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DIVER PROPULSION VEHICLE(U) NAVY EXPERIMENTAL DIVING
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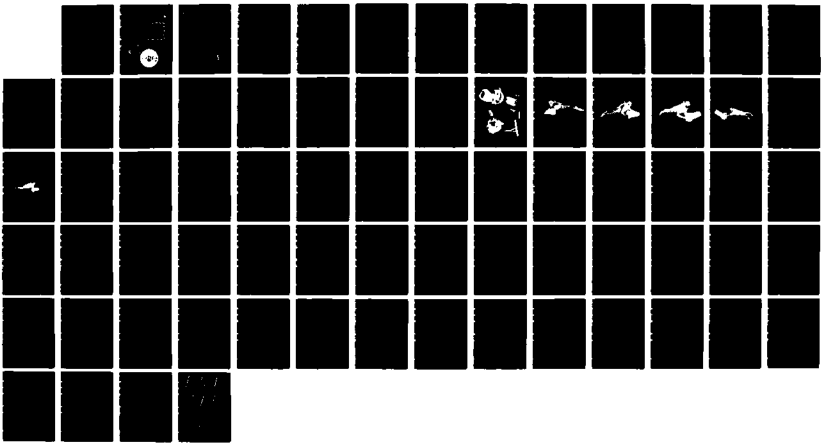

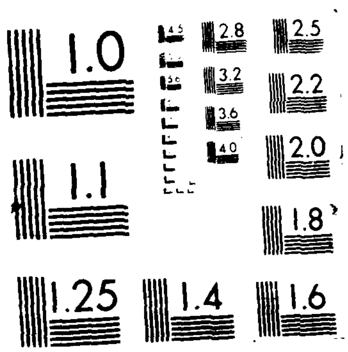
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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 9-87

# EVALUATION OF THE TEKNA DV-3X AND MIL-UNIT MOD S-5100 DIVER PROPULSION VEHICLE


CLARK G. PRESSWOOD
DAVID F. GODSHALL


AUGUST 1987

NAVY EXPERIMENTAL DIVING UNIT





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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

IN REPLY REFER TO:

NAVSEA Task 85-09

NAVY EXPERIMENTAL DIVING UNIT

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# EVALUATION OF THE TEKNA DV-3X AND MIL-UNIT MOD S-5100 DIVER PROPULSION VEHICLE

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## Abbreviations

| | |
|---|---|
| ANU | Authorized for Navy Use |
| DPV | diver propulsion vehicle |
| °C | degree celsius |
| °F | degree Fahrenheit |
| EMI | electromagnetic interference |
| FPM | feet per minute |
| FSW | feet of seawater |
| MMI | mechanical magnetic interference |
| MPH | miles per hour |
| NAVSEA | Naval Sea Systems Command |
| NCSC | Naval Coastal Systems Center |
| NEDU | Navy Experimental Diving Unit |
| PPM | parts per million |
| UBA | underwater breathing apparatus |
| yd | yard |

## Glossary

| | |
|---|---|
| Diver Propulsion Vehicle (DPV) | A device which tows, pushes, or otherwise drives a diver or subsurface swimmer through the water, normally by mechanical means, either assisted or unassisted by the diver himself. Normally held on to, or ridden externally by the diver. Also referred to as a swimmer propulsion unit (SPU). |
| knots | nautical miles per hour |
| nautical mile | 2000 yards |

## Abstract

NEDU Conducted an evaluation of the Tekna DV-3X and MIL-UNIT MOD S-5100 Diver Propulsion Vehicle (DPV). Static battery duration tests, open water/time distance trials, battery offgassing tests, and unmanned pressure tests were conducted. Both models were found to provide acceptable performance to a maximum depth of 130 FSW and are recommended for Authorized for Navy Use (ANU) status. Approximate run times and speeds on propeller pitch setting 9 was one hour at 1.6 knots. Reducing the propeller pitch setting will provide longer run times, longer distances, and reduced speeds.

KEY WORDS:

Diver Propulsion Vehicle (DPV)
NEDU Test Plan 85-25
NAVSEA Task 85-09
DV-3X model
MIL-UNIT MOD S-5100

## I. INTRODUCTION

Per NAVSEA Task 85-09, NEDU conducted an evaluation of the Tekna DV-3X and MIL-UNIT MOD S-5100 Diver Propulsion Vehicles (DPVs). Static battery duration tests in the NEDU test pool were conducted to evaluate the effects of cold temperatures, various propeller pitch settings, headlight on and off, and both continuous and intermittent power runs. Fast and slow battery charge cycles were evaluated. Open water time/distance runs were conducted to determine range and speed, suitability of optional equipment and overall DPV design, and optimum underwater procedures. Analysis of battery hydrogen offgassing evaluated DPV explosive hazard safety risks which may be generated by gas venting from the batteries. An unmanned pressure test evaluated maximum depth capability.

## II. EQUIPMENT DESCRIPTION

The DV-3X and MIL-UNIT MOD S-5100 DPVs are essentially the same product except that the MIL-UNIT is black vice red and contains components which are specially selected to provide a more efficient unit. Specifically, the MIL-UNIT model contains an electric motor which is no less than 80% efficient, whereas the DV-3X model normally contains a motor which is 70-80% efficient. The MIL-UNIT models reportedly undergo more stringent quality control testing at the factory, and are advertised to be quieter. Actual specifications for both units are provided as follows:

| | |
|---|---|
| Body Material: | Xenoy® resin |
| Headlight Protective Bezel Cowling: | Thermoplastic elastomer |
| Batteries: | Twin 12 volt, 15 ampere-hour suspended electrolyte rechargeable |
| Advertised Battery Life: | Approximately 200 charges |
| Charging Current: | 110 or 220 volt AC |
| Advertised Fast Charge Time: | 2-4 hours to 90% charge; 24 hours to 100% charge (all charge times assume deeply discharged battery at the onset of charging) |
| Advertised Normal Charge Time: | 6-12 hours to 90% charge; 24 hours to 100% charge |
| Advertised Charge Time With New Design Charger: | One charge mode: 1½ hours to 70% charge; 4 hours to 90% charge; 24 hours to 100% charge |
| Motor: | Barium ferrite permanent magnet, 600 rpm |

| | |
|---|---|
| Propeller Pitch Settings: | 9 |
| Advertised Running Time: | Variable 2 hours |
| Advertised Range: | Approximately 3 miles |
| Advertised Maximum Depth: | 130 feet |
| Advertised Speed: | Variable 1-3 MPH |
| Weight, in Air: | Approximately 48 pounds |
| Buoyancy, in Seawater: | Approximately 5 pounds 4 ounces negative |
| Buoyancy, in Fresh Water: | Approximately 6 pounds negative |
| Length: | 21.2 inches |
| Maximum Width: | 17.5 inches |
| Optional Equipment: | Cruise seat; gauge console (depth gauge and compass) |

## III. TEST PROCEDURES AND RESULTS

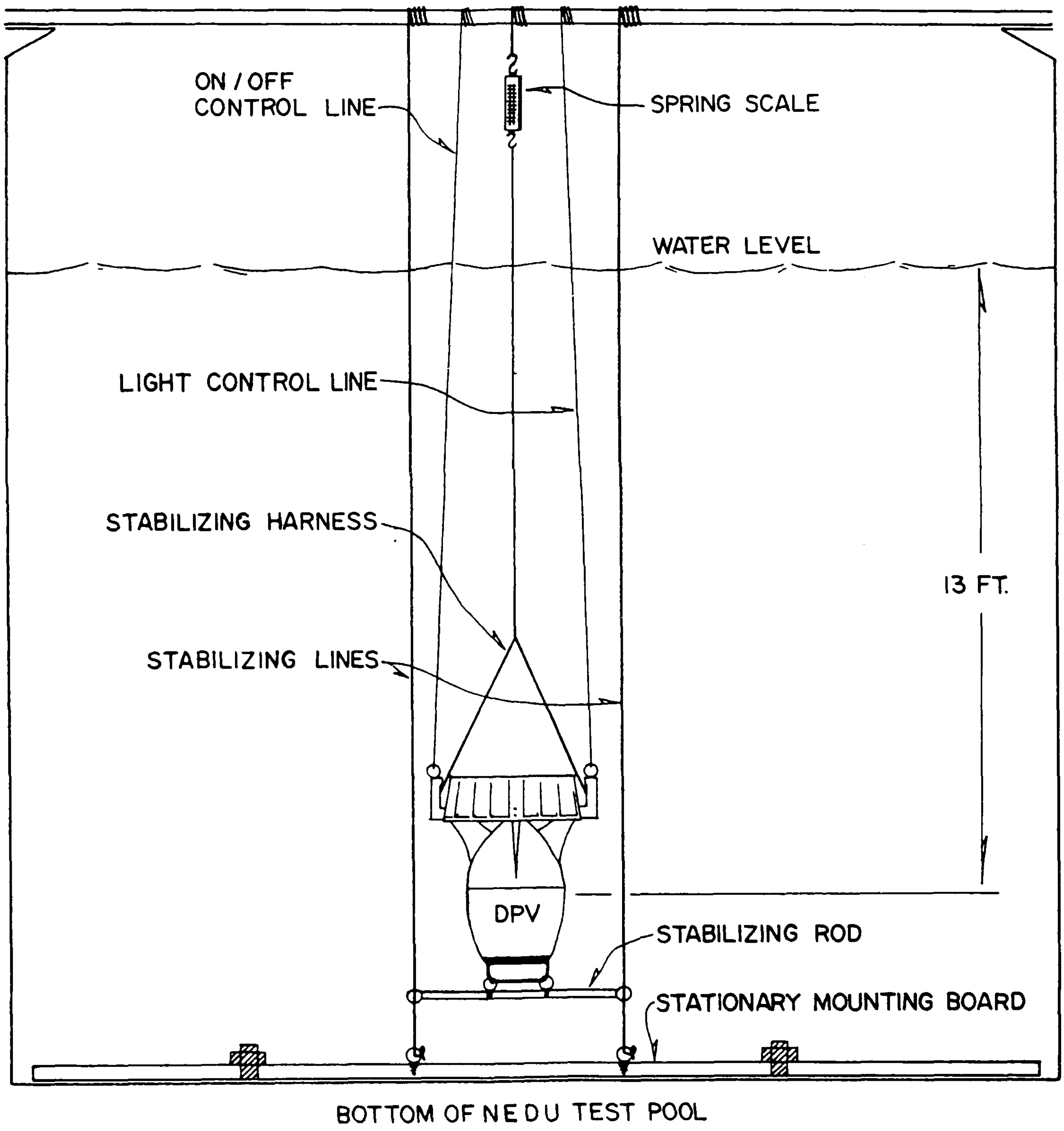
A. Static Battery Duration Tests. Unmanned static battery duration tests were conducted in the NEDU test pool to evaluate the effects of the following variables on static run times:

- Various water temperatures
- Intermittent and continuous running
- Various propeller pitch settings
- Fast and slow (normal) battery charge times (two charge modes available on original charge unit only)
- Headlight on and off

DPVs were static rigged on the bottom of the NEDU test pool at an approximate depth of 13 feet of freshwater. Figure 1 provides an illustration of the static test set up. The test set up allowed a maximum of four DPVs to be tested simultaneously. DPVs were lowered to the bottom and secured from the surface with stabilizing lines running from the bottom of the pool to the surface. Activation of power and headlight were controlled remotely from the surface by the use of shot cord attached to a modified trigger configuration. DPV rigging lines were attached to a spring scale on the surface to measure static thrust (which in turn revealed battery life status) and provide additional DPV stabilization during the static testing. All four spring scales used for the test were found to accurately record weight to within ±1 pound to a maximum capacity of 60 pounds.

FIGURE 1.

# DPV STATIC TEST SET UP



Four DPVs were submitted to the test. Two were DV-3X models and two were MIL-UNIT MOD S-5100 models. The red DV-3X models were designated #1 and #2, and the black MIL-UNIT S-5100 models were designated #3 and #4 for log keeping, data recording, and test reporting purposes.

It was assumed that static rigging of the DPVs would result in the units working much harder than would occur during normal open water operation. This would create extra stress on the units, resulting in an improved evaluation of DPV reliability during long term handling and repeated operation. The ability of DPV components to handle the increased stress would determine any weakness in component design and would result in heavily used units being submitted to follow up open water, battery offgassing, and depth capability testing.

Water temperature varied between 83° and 87°F during the initial static test phase. Testing was eventually delayed temporarily due to degradation of bearings and clutches on some units. Clutch damage became apparent on unit #3 on the 33rd dive after approximately 45 hours cumulative dive time. This occurred as a result of extensive propeller entanglement in the rigging lines. Revised static rigging procedures were developed to prevent propellor entanglement during further tests. DPV #4 also experienced clutch degradation. Clutch noise and gradual decrease of thrust was noticed on this unit after the 15th dive, representing approximately 22 hours total cumulative dive time. Clutch repair was accomplished after the 31st dive with 41 hours cumulative dive time. This unit had also experienced rigging line entanglement during the development of rigging procedures early in the test phase. DPV #2 experienced bearing noise on the 12th dive after approximately 27 hours cumulative dive time, which resulted in total bearing failure and loss of thrust after the 28th dive after approximately 36 hours run time.

It was apparent that DPV entanglement was the primary cause of clutch degradation. Entanglement was severe in both cases and resulted in excessive clutch slipping before power was secured, which provided considerable wear on the plastic clutch components. The specific cause of bearing degradation was not initially known. All units were returned to the factory for clutch repair, bearing repair, and installation of improved hydrogen absorption catalysts.

Discussions with the manufacturer indicate the old bearing cup seal design and tail cone configuration used on the units tested at NEDU allowed water to seep into the bearings, causing corrosion, increased noise, decreased efficiency, and generation of heat. This was found to be a problem in the sport diving market for vehicles manufactured before March 1986, and a new configuration was designed, modifying the cup seal and tail cone. This new design configuration was installed as a factory retrofit on the units tested at NEDU and testing was continued with cold water static duration tests. Continued testing would determine if the new design provided a satisfactory solution. The manufacturer indicated that DPV bearings have a lifetime warranty, whereas other DPV components have a one year warranty.

DPV #2 also experienced a broken handle suffered when the unit was tilted slightly to one side during lifting from a metal deck. When stored upright on

the propeller shroud, the handles protrude close to floor level, and tilting the unit to one side can bring the full weight of the DPV to bear on the plastic handle. Breaking the handle in this case resulted in the DPV failing in the 'on' position. Securing DPV power when this occurred was accomplished by pulling on the magnetic switch cable and securing the cable to the handle stub. Power is magnetically activated. Proper placement of an external magnet (hand held or clipped) to the right propeller shroud wing can also be used to activate or secure power if a handle casualty occurs. A new design plastic handle is reportedly in development by the manufacturer to reduce the occurrence of handle breakage and resulting failure mode. Structurally, the handle is the weakest part of the vehicle, and care must be taken when transporting the units.

Overall DPV usage prior to return of the units to the factory included initial open water familiarization swims, an operational search and recovery project, test pool static rigging development, and battery offgassing tests. Total cumulative dives/dive times completed upon the conclusion of the warm water test pool static run phase of testing and factory retrofit are as follows:

<u>DPV #1</u>

Total Dives: 37
Cumulative Dive Time: 49.5 hours
Discrepancies: none

<u>DPV #2</u>

Total Dives: 28
Cumulative Dive Time: 35.6 hours
Discrepancies:
(1) Right handle broke on dive #18. Repair was effected at that time.
(2) Increasing noise on dive #22, total loss of thrust on dive #28 (35.6 hours). Apparent bearing failure.

<u>DPV #3</u>

Total Dives: 33
Cumulative Dive Time: 44.75 hours
Discrepancies: static rigging lines tangled in propeller on dive #33; repair of clutch was necessary.

<u>DPV #4</u>

Total Dives: 31
Cumulative Dive Time: 40.9 hours
Discrepancies: clutch slipping noticed on dive #15 (28.6 hours); noise increased gradually with decrease in thrust, resulting in excessive noise, poor thrust, and warm clutch on dive #31 (40.9 hours). Static rigging line entanglement was the probable cause of clutch degradation.

Warm water static testing provided a wide variation of run times and thrust between the four units tested and on individual units for each dive. DPV #4 provided the widest spectrum of thrust variability on pitch setting 6 (24.5 to 30 pounds) and setting 9 (33 to 45.5 pounds). Thrust divergence from one dive to the next considerably effected duration data because the termination criteria for static duration tests was established as a decrease of net thrust to 30% of the initial value. This termination criteria appeared to be appropriate in that it prevented excessive battery discharge which might be detrimental to battery service life, and 30% remaining thrust represents an approximate point at which rapid battery depletion is in progress. Monitoring of battery voltage levels throughout the test dives would have provided a more precise termination criteria, but this would have required a difficult test set up procedure, including installing penetrators into the DPV housing or headlight which may have effected watertight integrity.

No significant impact on DPV duration attributable to light on/off, fast/normal charge times, or continuous/intermittent run times were evident. The manufacturer indicates that continuous light on runs may impact duration by as much as 3%. Fast or normal charge times are considered insignificant enough to have resulted in the design of a new charger which does not offer two charging modes, however the manufacturer specifies that sequential fast charges may contribute to a slight decrease (10%) in the number of charging cycles (battery service life) when the original charger is used. The duration of the charge on the single charge mode determines optimum battery life on the new charger, as listed in Section II of this report. A statistically significant evaluation of the effects of operational variables on total battery life would require that a greater number of dives be conducted under each test condition using units which did not suffer from bearing or clutch degradation during the test. Overall, these variables are not considered to be a significant cause of battery run time variability.

The wide variability of duration times and thrust seen on the four units may have been due to clutch slipping and bearing degradation that occurred at different times on three of the four units. When the retrofitted units were received for further testing, great care was taken to ensure no rigging entanglement occurred during cold water test runs, and thrust data was recorded at ten minute intervals during each test dive to provide a graph of thrust decrease with time.

The goal of static testing was to provide general information on the effects of various modes of operation and water temperatures, and provide increased handling and run time without the considerable logistic support that would be required for open water dives over a lengthy time frame. It was assumed that actual swimmer towed duration would normally be longer compared to static testing. Production of time verses thrust graphs during cold water static testing would also provide a means of more closely comparing power drops in both static and open water trials.

Charts and graphs of thrust verses time for static testing in water temperatures between 40°F and 70°F at 5°F intervals are provided in Appendix A. DPV #2 (DV-3X commercial model) and DPV #4 (military model) were

submitted to the test after factory retrofit with a new bearing seal configuration. Propellor pitch setting 9 was the only setting used for this portion of the test.

Examination of the static test run data at the various water temperatures indicates the two units were unaffected by differences in temperature. Long and short battery charge times provided similar run times. The MIL-UNIT model outperformed the DV-3X model in every case, providing run times from 4 minutes to 12 minutes longer, with an average of 8 minutes longer. Impressive repeatability of data is evident, which was not noticeable during previous static testing in warm water. This is a further indication that the wide variability of run times during the previous tests may have been due to bearing and clutch degradation occurring at different times on different units.

A total of 28 test runs were conducted on two units, with no problems occurring. Run times varied from 65 minutes to 75 minutes on the MIL-UNIT model, with an average of 69 minutes from 14 test runs. Run times varied from 58 minutes to 66 minutes on the DV-3X model, with an average of 60 minutes from the 14 test runs.

Initial static thrust varied from 36 to 42 pounds on the MIL-UNIT model, with an average of 39 pounds. On the DV-3X model initial static thrust varied from 36 to 38 pounds, with an average of 37 pounds.

It should be noted that these units were maintained at room temperature prior to immersion in cold water during this portion of the static test phase. Exposure to periods of cold air temperatures prior to immersion in cold water was not evaluated. If exposure to freezing temperatures occurs on depleted batteries, batteries should not be charged when frozen. A one hour warming time at room temperature (approximately 70°F or 21°C) for at least one hour prior to charging is recommended by the manufacturer.

This test completed the static test phase of the evaluation. All four units were then submitted to open water time/distance trials.

B. <u>Open Water Time/Distance Trials</u>

1. Test Procedure. All four DPVs were submitted to manned time/distance trials to determine range, speed, and duration in an open water environment, and to provide diver feedback on overall suitability and optimum use of the units. A 100 yard polypropylene line was staked on the bay bottom in a sandy, grassy area at an approximate depth of 8 FSW. Divers wore a single open circuit SCUBA tank with regulator and pressure/depth gauge console. One eighth inch wet suits were worn with fins, booties, face mask, and horsecollar style Seatec or MK 4 life preservers with low pressure air inflators installed. Divers used either the DV-3X or MIL-UNIT DPV with compass/depth gauge console and cruise seat installed. One hundred eighty degree turns were required every 100 yards on transit which may have resulted in the loss of two or three seconds on each turn. A boat was stationed at one end of the 100 yard line. The surface support crew recorded total dive time and diver split times every 200 yards, thus enabling a computation of speed over the bottom at 200 yard intervals.

Two of the divers were of tall, slender build, weighing 190 pounds and 170 pounds respectively, and two of the divers were of medium build, weighing 160 and 157 pounds. Divers alternated DPVs during the trial runs. The manufacturer indicates that the best combination of speed, run time, range and comfort are achieved at propeller pitch settings between 3 and 5. Open water pitch settings of 6 and 9 were evaluated because it was assumed the higher settings would be the settings of choice by military divers. An advantage of the different propeller settings is it allows divers of different size and drag to maintain close proximity to each other by adjusting pitch settings accordingly.

The time at which an individual dive was aborted was subjectively determined. It was decided that divers would abort the dive when the DPV no longer pulled the diver at a speed faster than normal swim speed (assumed to be approximately 0.8 to 1.0 knot) or DPV performance became so lackluster as to not provide the diver with enough power to maintain a consistent course. This termination criteria resulted in diver aborts at slightly different times, however the number of resulting laps on the different DPVs was similar during the given kicking (swimming) or resting modes, and major DPV power reduction was relatively easy to determine during in-water use. This test procedure provided an accurate method of determining diver towed speed at 200 yard intervals, speed reduction over time, and average speed over the entire course.

Each of the four DPVs were tested twice at pitch setting 9, continuous running with no propulsion assistance from the diver (diver resting). Each unit was then tested once at pitch setting 9 with the diver providing propulsion assistance by kicking his fins at a relaxed, comfortable pace (diver swimming). All units were then tested at pitch setting 6 with diver resting, and again at pitch setting 6 with diver swimming. All units were fast charged. Bay water temperature was approximately 76°F. Test results are provided in Appendix B.

A synopsis of open water testing is provided in the charts that follow:

COMMERCIAL MODEL, PITCH SETTING 9, RESTING DIVER

| DPV # | DISTANCE (YARDS) | TIME | AVERAGE SPEED (KNOTS) | DIVER BUILD |
|---|---|---|---|---|
| 1 | 3000 | 67 min 20 sec | 1.5 | medium |
| 1 | 3000 | 55 min 15 sec | 1.6 | tall, slim |
| 2 | 3200 | 66 min 30 sec | 1.5 | tall, slim |
| 2 | 3200 | 61 min 40 sec | 1.6 | medium |

| MILITARY MODEL, PITCH SETTING 9, RESTING DIVER | | | | |
|---|---|---|---|---|
| DPV # | DISTANCE (YARDS) | TIME | AVERAGE SPEED (KNOTS) | DIVER BUILD |
| 3 | 2400 | 55 min 40 sec | 1.4 | tall, slim |
| 3 | 2800 | 48 min 25 sec | 1.7 | tall, slim |
| 4 | 3200 | 67 min 22 sec | 1.5 | medium |
| 4 | 2800 | 50 min 12 sec | 1.7 | medium |

| COMMERCIAL MODEL, PITCH SETTING 9, SWIMMING DIVER | | | | |
|---|---|---|---|---|
| DPV # | DISTANCE (YARDS) | TIME | AVERAGE SPEED (KNOTS) | DIVER BUILD |
| 1 | 3200 | 51 min 05 sec | 1.9 | medium |
| 2 | 3600 | 65 min 10 sec | 1.7 | tall, slim |

| MILITARY MODEL, PITCH SETTING 9, SWIMMING DIVER | | | | |
|---|---|---|---|---|
| DPV # | DISTANCE (YARDS) | TIME | AVERAGE SPEED (KNOTS) | DIVER BUILD |
| 3 | 3000 | 49 min 49 sec | 1.8 | tall, slim |
| 4 | 3000 | 47 min 10 sec | 1.9 | medium |

| COMMERCIAL MODEL, PITCH SETTING 6, RESTING DIVER | | | | |
|---|---|---|---|---|
| DPV # | DISTANCE (YARDS) | TIME | AVERAGE SPEED (KNOTS) | DIVER BUILD |
| 1 | 3400 | 88 min 35 sec | 1.2 | tall, slim |
| 2 | 3000 | 66 min 30 sec | 1.4 | medium |

| MILITARY MODEL, PITCH SETTING 6, RESTING DIVER | | | | |
|---|---|---|---|---|
| DPV # | DISTANCE (YARDS) | TIME | AVERAGE SPEED (KNOTS) | DIVER BUILD |
| 3 | 3200 | 60 min 5 sec | 1.6 | tall, slim |
| 4 | 3600 | 66 min 15 sec | 1.7 | medium |

| COMMERCIAL MODEL, PITCH SETTING 6, SWIMMING DIVER | | | | |
|---|---|---|---|---|
| DPV # | DISTANCE (YARDS) | TIME | AVERAGE SPEED (KNOTS) | DIVER BUILD |
| 1 | 3400 | 74 min 45 sec | 1.4 | tall, slim |
| 2 | 4200 | 81 min 50 sec | 1.5 | medium |

| MILITARY MODEL, PITCH SETTING 6, SWIMMING DIVER | | | | |
|---|---|---|---|---|
| DPV # | DISTANCE (YARDS) | TIME | AVERAGE SPEED (KNOTS) | DIVER BUILD |
| 3 | 4000 | 73 min 31 sec | 1.7 | tall, slim |
| 4 | 4400 | 77 min 22 sec | 1.7 | medium |

2. Test Results. Diver air consumption on a single 80 or 92 cubic foot open circuit SCUBA tank varied from 750 to 1500 psi at the 8 FSW depth during the resting diver mode. The swimming diver mode resulted in air consumption in excess of 2500 psi in every case. It is evident that DPV swims in a resting mode decreases air consumption by as much as 50% or more. Diver oxygen consumption would also decrease by an indeterminate amount, however this was not evaluated, and would depend on the actual dive profile.

The lighter, medium build divers experienced slightly faster and longer dives overall. Overall, the MIL-UNIT models were slightly faster. Overall total distances covered were similar on both military and commercial units on both pitch settings. The longest distance was provided by DPV #4 (military model, 4400 yards, pitch setting 6, average 1.7 knots) in the swimming diver mode, whereas the longest time was provided by DPV #2 (commercial model, 81 minutes 50 seconds, pitch setting 6, average 1.5 knots) in the swimming diver mode.

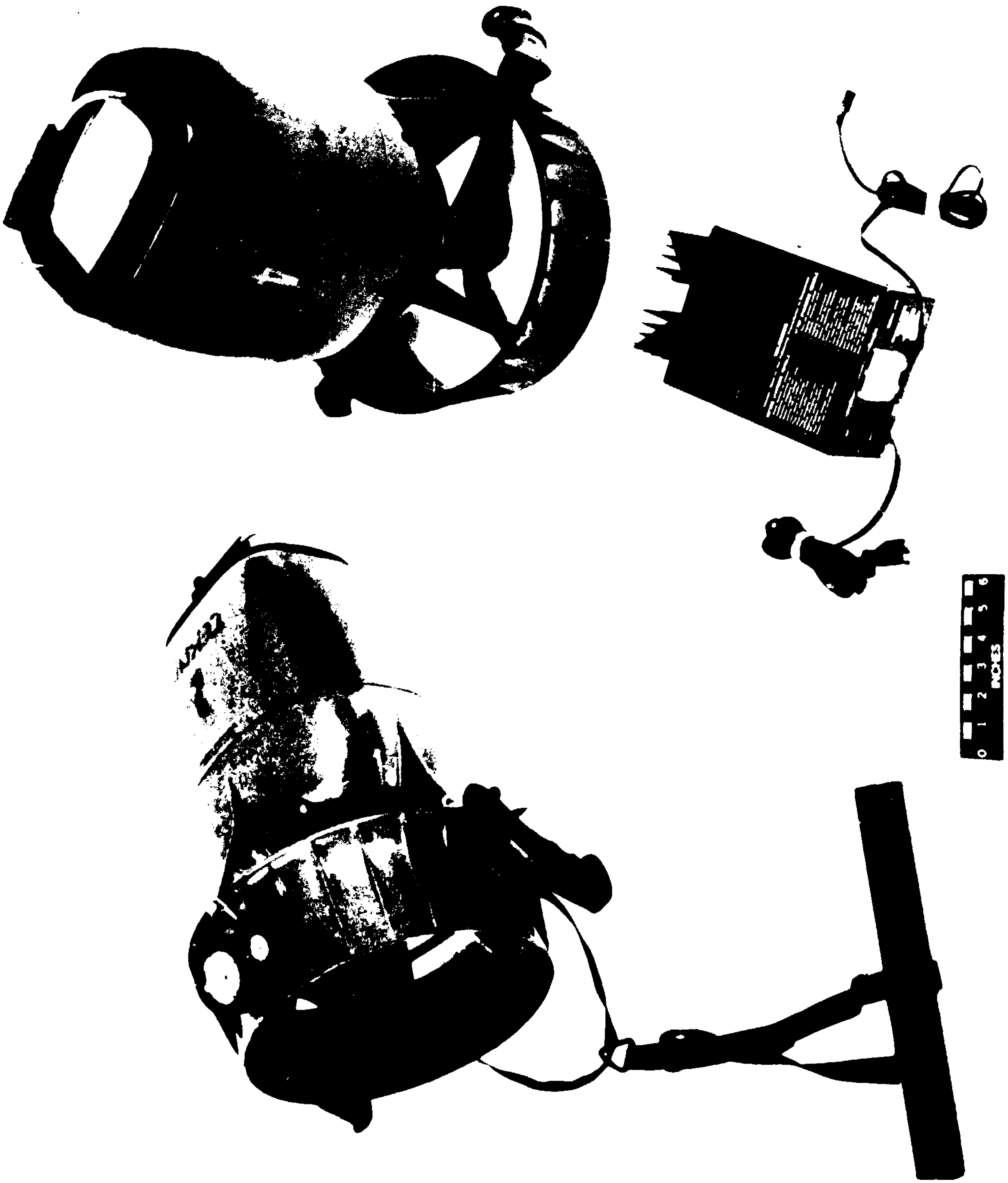
In the resting diver mode, DPV open water duration times proved to be very similar to test pool static duration times on pitch setting 9. Approximate run times of one hour can be anticipated. The close correlation of static and open water run times was not anticipated, but is an indication that static testing is a reasonable test technique for inclusion in the DPV evaluation.

Average resting speeds on all units varied from 1.4 to 1.7 knots on pitch setting 9 (overall resting average 1.6 knots). Average swimming speeds on all units varied from 1.7 to 1.9 knots on pitch setting 9 (overall swimming average 1.8 knots).

Average resting diver speeds on all units varied from 1.2 to 1.7 knots on pitch setting 6 (overall resting average 1.5 knots). Average swimming diver speeds on all units varied from 1.4 to 1.7 knots on pitch setting 6 (overall swimming average 1.6 knots).

3. Optional Equipment and Underwater Techniques. The open water tests provided the opportunity to evaluate the suitability of optional equipment (cruise seat, compass/depth gauge console) and preferred underwater techniques for use during various modes of operation. The cruise seat consists of a plastic bar attached to a fabric strap which branches, or forms a "Y" to provide two bitter ends for attachment to the base of each DPV handle (Figure 2). Use of the cruise seat was preferred by all four divers who participated in the continuous operation open water evaluation. The seat proved to be comfortable, easy to use, and relieves the stress on the arms which would otherwise occur. The cruise seat is adjustable to diver comfort, and all divers agreed that the preferred adjustment length would position the center of the DPV at about neck or head level (Figures 3 and 4). DPV management would then be controlled primarily with the left hand grasping the front of the DPV at either the headlight protective bezel cowling or the carrying handle. The right hand could then be used to activate the power switch, although experimentation determined the optimum method of power activation to be use of a large o-ring which could be rolled on or off the power activation switch during a dive. This procedure would only be preferable during continuous, extended operation of the DPV, and care must be taken not to lose control of the unit when activating power in this way, as the diver could lose the unit. For this reason, grasping the carrying handle with the left hand may be preferable to grasping the headlight cowling. Maintaining control of the units did not prove to be a problem during open water testing.

Figures 5 and 6 provide illustrations of alternative modes of DPV operation. The primary consideration in DPV operation is in preventing DPV backwash from flowing across the divers body. Although the bent arm technique shown in Figure 5 is the optimum mode recommended by the manufacturer and may be the preferable mode when a cruise seat is not used, Figure 6 illustrates an optional extended arm technique which proved to work quite well on short duration dives and reduces arm fatigue, although hand fatigue can occur as a result of the requirement to grasp the very top of the handles. A limitation of the extended arm technique is that the compass/depth gauge console, when



ENA DPV WITH CRUISE
AT, CONSOLE AND CHARGER

FIGURE 3: CRUISE SEAT APPLICATION,
LEFT ARM VIEW

FIGURE 4: CRUISE SEAT APPLICATION,
RIGHT ARM VIEW

FIGURE 5: BENT ARM TECHNIQUE

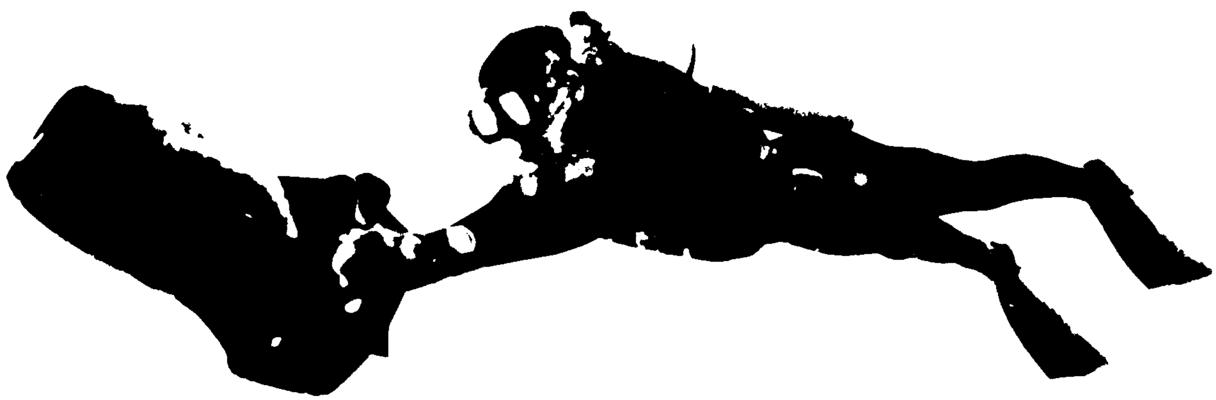


FIGURE 6: EXTENDED ARM TECHNIQUE

used, is maintained at a farther distance from the diver, making it more difficult to see. Additionally, this technique was not evaluated for range and speed and may cause additional drag through the water.

The bent arm technique recommended by the manufacturer can also be used with the cruise seat, and this would relieve stress on the divers arms. Figure 7 provides an illustration of a one armed cruise seat technique using an o-ring to activate power. Figure 8 provides an illustration of propeller pitch adjustment knob.

The compass/depth gauge console is designed to mount on the top of the propeller shroud. This location is suitable when the bent arm technique is used, however when the cruise seat method described above is used, the console should be mounted on the front of the DPV. Mounting procedures for this application were not evaluated.

The Tekna compass provides direction finding capabilities in a small lightweight configuration, however fine control of direction is not as easy compared to larger compasses. Mounting a large compass on the DPV is more difficult, and could be broken off easily if not properly configured. Two different "globe" type compasses (Richie, Benz) were evaluated for compatibility with the Tekna DPV. It was found that electromagnetic interference (EMI) from the DPV motor caused errors in all compasses which were evaluated.

Compass deviation occurs when compasses are brought within close proximity of the DPV when the DPV is not running. This is caused by the magnets and metal parts within the DPV. For clarification purposes, this is referred to as Mechanical Magnetic Interference (MMI). Compass deviation also occurs due to Electromagnetic Interference (EMI) when the DPV is activated, due to the current field created by the electric motor. Deviation can be minimized by selecting the optimum mounting location for the particular swimming application. All compasses evaluated were found to deviate the least (2° to 5°) when mounted near the headlight. Compass mounting in the vicinity of the headlight was also found to be the preferred mounting position when the cruise seat swimming method is used. Compasses deviated the most when mounted directly in front of the propeller, over the electric motor (up to 30° deviation). A deviation of 3° to 7° occurred when mounted on the propeller shroud. The amount of deviation may vary in each location dependent upon the directional orientation of the DPV, and upon the propeller pitch setting and battery charge of the DPV. It may be preferable to consider compass mounting in an area which provides the most consistent deviation, so that deviation corrections can be made to the compass, however corrections cannot be made which will account for all deviation variables.

Fishing line monofilament and seagrass entanglement in the propeller occurred during open water tests. Swimming on the bottom in areas of heavy sea grass or bottom kelp should be avoided. Seagrass was easily removed by stopping the DPV and manually removing the obstruction, or by cycling the motor on and off. Monofilament must normally be manually removed. Propeller entanglements or obstructions should always be removed immediately. If a

FIGURE 7: ONE ARM CRUISE SEAT TECHNIQUE

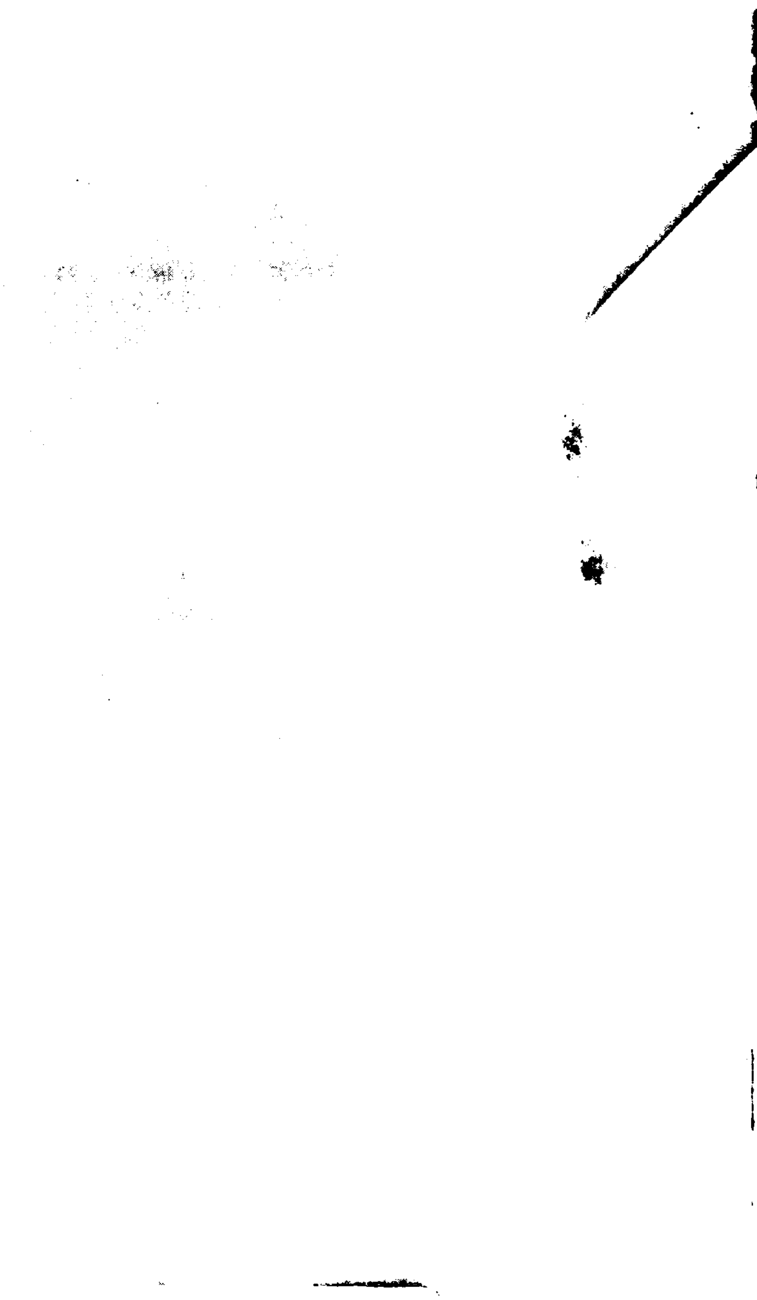


FIGURE 8: PROPELLOR PITCH ADJUSTMENT KNOB

grinding or rapid clicking noise is heard at any time, the DPV should be immediately stopped and checked for an obstruction. This sound is the clutch slipping, which could result in rapid degradation of the plastic clutch components. The clutch is designed to slip, so that damage to propeller blades, diving equipment, or personal injury does not occur, however excessive clutch slipping will wear down the clutch. Replacement of a worn clutch is not difficult if proper procedures contained in the Tekna maintenance manual are followed.

Clutch slipping was noted in isolated cases during open water trials due to life preserver body or inflators being dragged into the propeller. No life preserver or propeller damage occurred. A disadvantage of the cruise seat application mode discussed in the preceding paragraphs is that equipment can be drawn into the propeller due to body position in relation to the DPV if care is not taken. No permanent clutch degradation was noticed during this test phase.

Four removable plastic propeller screens are provided on each DPV to prevent large objects from being dragged into the propeller. These screens were not used during the open water time/distance trials because they tend to fall off if jarred, and can be lost. Use of a screen system is appropriate to prevent equipment from being drawn into the propeller, however care should be taken to install the screens so they do not come loose. Smaller diameter continuous loop metal screens may be preferable, but are not available from the manufacturer. Use of RTV in the connection ports was evaluated as a possible improvement with the plastic screen configuration, but screens can still come loose due to their flexible plastic modular construction. It is probable that these screens may also provide additional drag, and reduce DPV performance by an indeterminate, minor amount. The screens will probably not prevent monofilament, seaweed, or kelp entanglement.

On one occasion power was inadvertently activated while carrying the DPV, with the operators hand inside the shroud. Clutch slipping occurred without skin damage to the operator, which is an indication of an important safety feature in design clutch tolerance.

Diver streamlining is an important aspect of maximum DPV performance. Simply lifting the head to clear a dive mask can provide noticeable drag. First time DPV users may not obtain the same speed, distance, and run times as experienced DPV users who have learned to maintain a streamlined body position and keep extraneous equipment and poorly contoured diver garments to a minimum.

Exceeding the safe ascent rate of 60 FPM is possible during power ascents. It is essential that divers monitor their ascent and descent rates when using a DPV. This is emphasized on the proposed DPV pre/post dive checklist provided by Figure 9.

4. Battery Charging. The design of the units does not allow rapid battery changes between repetitive dives. Batteries are semipermanently fixed in the units and should be recharged after each use. Recharging is conducted by installing the charger plug into the port provided on the DPV case. The

DPV PRE/POST DIVE CHECKLIST

DIVER: ______________________ EVOLUTION: ______________________

DPV #: ______________________ DATE: ______________________

PRE-DIVE

Initials

______ 1. 30 minutes after charging, replace charging port plug.
______ 2. Visually inspect DPV for damage/cracks, etc.
______ 3. Test headlamp/on-off switch for smooth operation.
______ 4. Dip test DPV for leaks (if leaking refer to maintenance manual).
______ 5. Adjust propeller pitch setting to desired pitch.
______ 6. If the cruise seat is used, adjust harness before attempting long distance swims.

REPORT ANY DISCREPANCIES: ______________________________

______________________________________________________

______________________________________________________

CAUTION: (A) IMMEDIATELY TURN OFF DPV AND REMOVE ANY OBSTRUCTIONS WHILE IN USE.
(B) DO NOT DRAIN BATTERIES BY OVERUSE.
(C) DO NOT EXCEED SAFE ASCENT/DESCENT RATES.

POST-DIVE

Initials

______ 1. Rinse DPV with fresh water.
______ 2. Test headlamp/on-off switch for smooth operation.
______ 3. Visually inspect DPV for damage/cracks, etc.
______ 4. Remove charging port plug and begin charge cycle.

NOTE: If you suspect any leakage, refer to the maintenance manual and remove specified parts to inspect.

REPORT ANY DISCREPANCIES: ______________________________

______________________________________________________

______________________________________________________

Figure 9. Proposed DPV Pre/Post Dive Checklist

battery charger supplied with each unit includes a slide switch to select voltage supply at 110 or 220 volts. It is important to set the proper voltage before charging to avoid damage to the unit. The batteries cannot be overcharged, as the charger will automatically reduce the charge rate when batteries are fully charged. An analog current meter is provided on the charger. The indication needle provides DC charge amperes (up to 5 amps), and will gradually move to the left, and finally close to zero as the batteries reach full charge. The manufacturer recommends that 30 minutes elapse before replacing the charging port plug after the battery charge is complete, to allow excess hydrogen to dissipate. When operational needs require immediate use after charging, this would be safe on those units which contain the new catalytic belts, as indicated by the low levels of hydrogen found during hydrogen offgassing tests discussed in Section III.D.

The manufacturer recommends storing the unit with the charging port plug removed, and recharging expended batteries within 24 hours after use. Failure to reinstall the plug in the charging port will result in DPV floodout. Deeply discharging batteries during operational use is not recommended by the manufacturer, nor is undercharging batteries during the charge cycle.

Exposing the charger to fresh or salt water spray may damage or destroy the charger. Charging should be conducted in a well ventilated area away from spark or flames. On the dual charge mode charger, normal charge rate is recommended by the manufacturer for optimum battery life, as sequential fast charges may contribute to a slight decrease in the number of charging cycles, or battery service life (by approximately 10%).

C. Pressure Test. All units were submitted to two leak tests. Units #1 and #3 were submerged in a tank filled with fresh water inside a test chamber and pressed to 130 FSW for 30 minutes. Power was not activated during this test. These units were then disassembled to check for leaks, and then submitted to a 170 FSW dive for 30 minutes, static rigged with power activated, followed by another disassembly and internal leak check. Units #2 and #4 were tested in the same manner, except these units were static rigged in a fresh water tank and power was activated during the 130 FSW dive, and were then tested without power activation on the 170 FSW dive. Propeller pitch setting 1 was used on the units which were power activated during the dive. No leakage was found on any of the units. All units were also vacuum tested before and after each test with a vacuum tester provided by the manufacturer, with positive results.

Advertised maximum depth on these units is 130 FSW. The units are factory tested at 170 FSW, therefore the leak test conducted at NEDU utilized these two depths. The manufacturer informed NEDU that when leaks occur, the source of leaks is normally from failing to reinstall the charge port plug, or through the headlight, which could flex as a result of excessive pressure. The manufacturer indicates that leaks would normally be expected at 200 to 250 FSW. Although no leaks occurred during the 170 FSW dives, the 130 FSW depth limitation is considered appropriate to prevent DPV floodout. A flooded DPV would be quite negatively buoyant, and would be difficult to bring to the

surface. A partially flooded DPV will likely be operational, and can be powered to the surface. Buoyancy of unflooded DPV is approximately 5 pounds 4 ounces negative in salt water. A neoprene sleeve which fits around the DPV body could be utilized to provide additional buoyancy, if desired, although this could provide a very slight amount of additional drag.

The Tekna DPVs may be leak tested at any time using a vacuum pump available from the manufacturer. This should be done if the upper housing must be entered for maintenance, to ensure o-ring seal integrity has been established upon reassembly.

D. Battery Hydrogen Offgassing Test. The original version of the Tekna DPV included small catalytic discs installed inside the battery compartment for the absorption of hydrogen which may be vented by the batteries. The currently Authorized for Navy Use (ANU) Farallon DPV is purged with nitrogen prior to use to offset the hazards of hydrogen buildup. Concern over the effectiveness of these discs, especially if inadvertently wetted, resulted in the development of large catalytic belts. Both disc and belt catalysts include a dessicant to absorb moisture. Significant leaks will consume the desicant and render the catalyst ineffective, therefore DPV floodouts or leaks are cause to replace the entire catalyst system. When the DPVs in the custody of NEDU were returned for factory retrofit, the new catalytic belts were installed.

The battery compartment of the DPV was sampled for hydrogen content by fitting a Whitey valve with compatible thread sizes into the battery charge plug. Samples were taken at various times in the DPV test cycle, and analyzed for hydrogen content. It has been determined elsewhere that a minimum of 3% by volume (30,000 ppm) hydrogen content in air may result in an explosion due to sparking within the battery compartment.

As soon as the retrofitted units were received (new catalysts installed), a single DPV (#2) was given an overnight charge, fitted with a sampling valve, and submitted to a dive in excess of one hour to deplete battery power. A gas sample was then drawn within one hour of dive conclusion. This sample was analyzed using a gas chromatograph at the Naval Coastal Systems Center (NCSC) Gas Laboratory. The hydrogen level present was found to be approximately 50 ppm.

Follow up tests were conducted on other units during the static and open water test phases. All samples were taken within 1 hour of total battery depletion, except for the second test on DPV #2 which was taken after 24 hours. This test resulted in low hydrogen levels (<100 ppm), possibly due to hydrogen escape from the DPV housing during the 24 hour storage time. Results are provided as follows:

DPV #4
Total dives after installation of catalytic belts: 16
Cumulative dive time after installation of catalytic belts: 18 hrs 25 min
Gas sample result: 798 ppm

DPV #2
Total dives after installation of catalytic belts: 18
Cumulative dive time after installation of catalytic belts: 18 hrs
Gas sample result: < 100 ppm

DPV #2
Total dives after installation of catalytic belts: 20
Cumulative dive time after installation of catalytic belts: 22 hrs 30 min
Gas sample result: 588 ppm

It is apparent that hydrogen levels on all tests were well within safety parameters.

## IV. DISCUSSION

A. Operational Variables. DPV range and speed is contingent upon numerous variables, including diver size, resting or swimming (diver assisting DPV with swim fins), optimum battery charging, and diver familiarity and streamlining. The effects of cold water (when units were kept warm prior to immersion), headlight illumination, and intermittent running are considered minimal. Normal and fast battery charge times did not provide noticeable differences in run time duration. The effects of alternative underwater breathing apparatus (UBA) and diver garment configurations was not evaluated, but it is reasonable to assume that low profile equipment configurations will provide an advantage, and this would be true of a free swimming diver as well. Tides and current should always be used to maximum advantage to achieve maximum distance and speed.

The primary duration variable is propeller pitch settings. Durations of approximately one hour can normally be expected on pitch setting 9 in a resting diver mode. This setting provides worst case duration and maximum speed. Average speed on the DV-3X and MIL-UNIT DPVs on this pitch setting was 1.6 knots during open water tests. Longer run times and slower speeds can be expected at other pitch settings. Longer distances were achieved on pitch setting 6 compared to pitch setting 9. Diver kicking (swimming) will increase speed, distance, and diver air or oxygen consumption, but will not normally increase battery duration time.

B. Durability. During the initial phase of static battery duration tests, down time was incurred as a result of clutch and bearing degradation and handle breakage. The clutch slipping which occurred on two units is attributable to static test rigging line entanglement in the propeller which was not immediately noticed and rectified. Further static and open water testing did not result in clutch problems and undue clutch wear should not normally prove to be a problem if proper precautions are taken when kelp, seaweed, monofilament, or diver equipment propeller entanglements occur. Clutch slipping is an important safety feature to ensure no equipment damage or personal injury occurs. If clutch wear occurs, replacement is simple at the operator level by following the procedures provided by the Tekna maintenance manual. This manual is generally well done and should be maintained by all diving lockers utilizing the DPVs.

Bearing failure occurred on one unit, apparently due to the bearing cup seal allowing water to seep into the bearings, causing bearing corrosion. This problem surfaced in the commercial market for vehicles manufactured before March 1986, and required that a new cup seal and tail cone configuration be designed. The new configuration proved to operate satisfactorily during the final portion of static testing, and during open water testing, pressure testing, and hydrogen offgassing tests.

Structurally, DPV handles are the weakest part of the vehicle. Handle breakage occurred on one unit when the DPV was tilted during hoisting. A new design plastic handle is reportedly in development by the manufacturer. The plastic construction of the entire DPV makes the units subject to breakage if improperly handled. This is not a major concern during in-water use, but care must be taken when transporting the units to and from the dive site.

A possible advantage of the plastic construction of the units is lighter weight. Although fiberglass or lightweight metal may be preferable for military application, the plastic construction of the Tekna DPV should provide a reasonable degree of reliability for most applications if extra care is taken in handling the units, particularly if the handles are protected from impact.

The conduct of maintenance on the Tekna DPVs is not difficult. An adequate maintenance manual is available from the manufacturer, and most repairs can be conducted at the operator level. For major repairs, individual units or unit components should be returned for factory repair or replacement.

C. Safety. The DPV clutch will adequately disengage the propeller to prevent equipment or personal damage in most all circumstances. Battery hydrogen levels were found to be well below the dangerous limit during battery offgassing testing. The new belt catalysts should always be used, vice the old disc catalysts. Catalysts should be replaced when batteries are replaced, or when a DPV floodout occurs. Divers must always carefully monitor ascent and descent rates when using a DPV.

## V. CONCLUSION

Use of Diver Propulsion Vehicles in the U.S. Navy diving may have numerous applications. This report places a focus on time/distance runs for application to extended compass course swims, however the units within the NEDU inventory were also utilized during a downed aircraft search and salvage project, with positive results. DPV search techniques would require further development, but the potential for DPV application is noteworthy.

It is recommended that the Tekna DV-3X and MIL-UNIT MOD S-5100 be Authorized for U.S. Navy Use. The manufacturers prescribed depth limitation of 130 FSW is considered appropriate. This may limit operational use in some circumstances. These units should be handled with care during transport, which is generally true of most diving equipment. The MIL-UNIT model will provide slightly improved overall performance over the commercial DV-3X model.

# APPENDIX A

## DPV STATIC DURATION DATA
## NET THRUST VERSES TIME

One chart and one graph is provided for each of the two DPVs at each test water temperature between 40°F and 70°F at 5°F increments.

KEY:

Figure A1: DPV Static Duration Chart at 40°F Water Temperature
Figure A2: DPV Static Duration Graph at 40°F Water Temperature
Figure A3: DPV Static Duration Chart at 45°F Water Temperature
Figure A4: DPV Static Duration Graph at 45°F Water Temperature
Figure A5: DPV Static Duration Chart at 50°F Water Temperature
Figure A6: DPV Static Duration Graph at 50°F Water Temperature
Figure A7: DPV Static Duration Chart at 55°F Water Temperature
Figure A8: DPV Static Duration Graph at 55°F Water Temperature
Figure A9: DPV Static Duration Chart at 60°F Water Temperature
Figure A10: DPV Static Duration Graph at 60°F Water Temperature
Figure A11: DPV Static Duration Chart at 65°F Water Temperature
Figure A12: DPV Static Duration Graph at 65°F Water Temperature
Figure A13: DPV Static Duration Chart at 70°F Water Temperature
Figure A14: DPV Static Duration Graph at 70°F Water Temperature

Figure A1

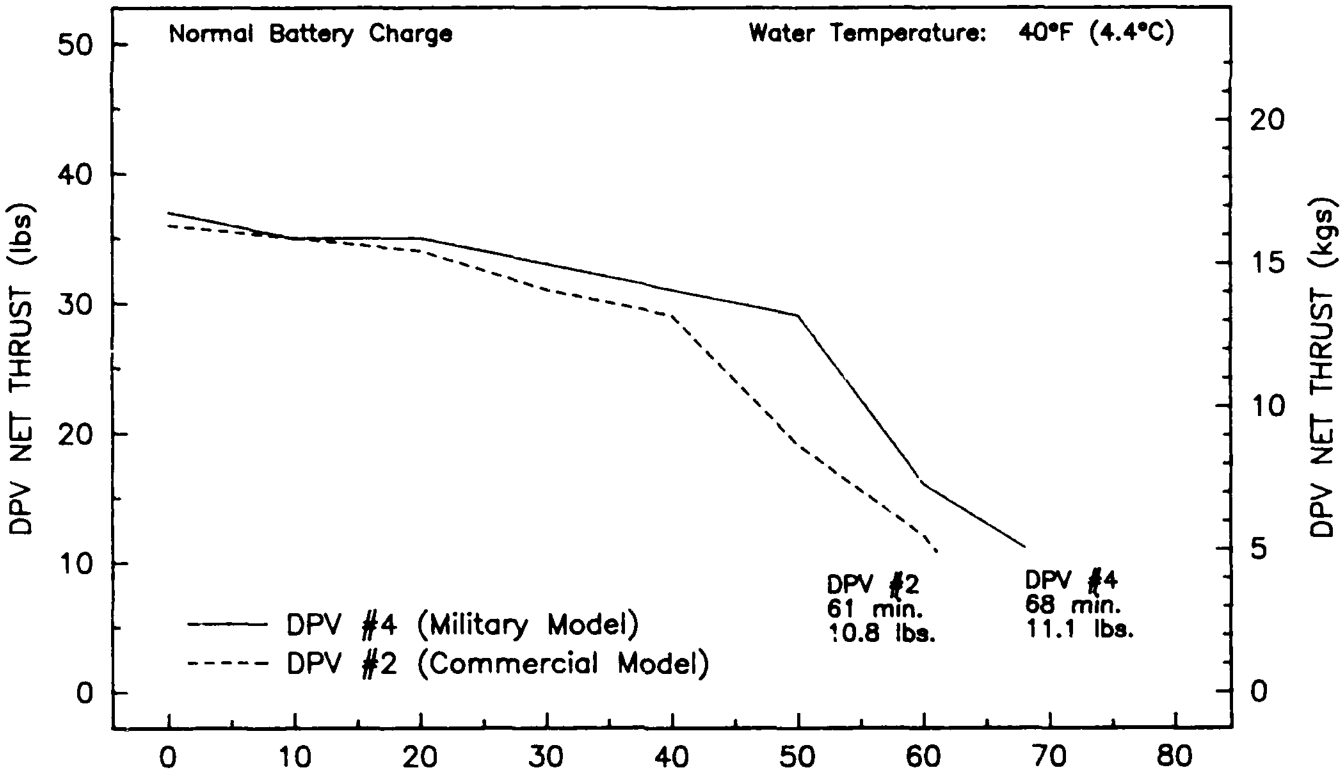
| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|---|---|
| | DPV STATIC DURATION CHART, 40°F (4.4°C) WATER TEMPERATURE<br>DIVE #1<br>NORMAL BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
| DPV #4 | Net Thrust (Pounds) | 37 | 35 | 35 | 33 | 31 | 29 | 16 | 11.1 (68 min) |
| DPV #2 | | 36 | 35 | 34 | 31 | 29 | 19 | 12 | 10.8 (61 min) |

DPV #4 (Military Model) Duration to 30% Net Thrust: 68 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 61 Minutes

| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| | DPV STATIC DURATION CHART, 40°F (4.4°C) WATER TEMPERATURE<br>DIVE #2<br>FAST BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | | |
| DPV #4 | Net Thrust (Pounds) | 38 | 36 | 35 | 33 | 33 | 32 | 22 | 15 | 11.4 (75 min) |
| DPV #2 | | 38 | 36 | 34 | 32 | 30 | 18 | 12 | 11.4 (61 min) | |

DPV #4 (Military Model) Duration to 30% Net Thrust: 75 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 61 Minutes

TEKNA DIVER PROPULSION VEHICLE NET THRUST vs TIME
Unmanned Static Test. Propeller Pitch Setting 9.
Duration to 30% of Starting Net Thrust.



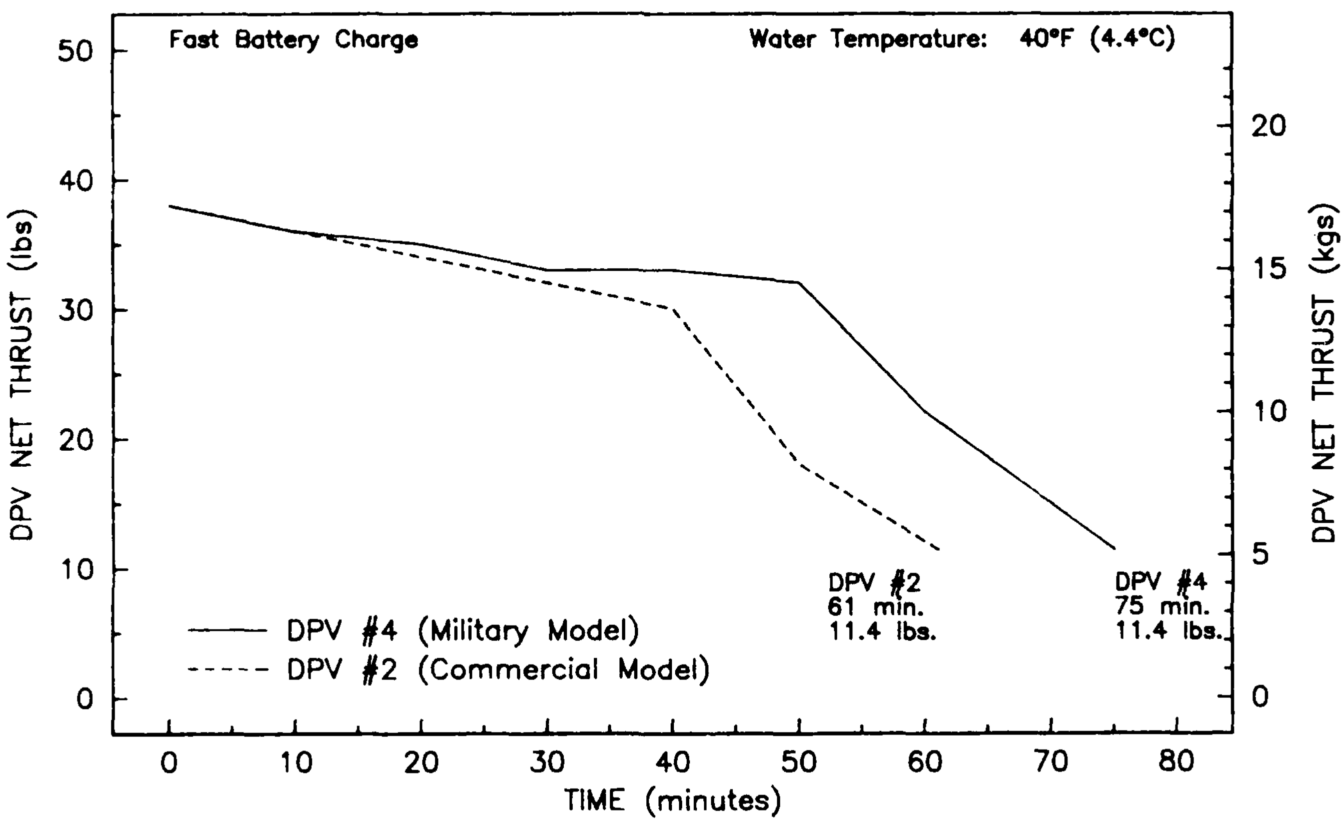



Figure A3

| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|---|---|
| | **DPV STATIC DURATION CHART, 45°F (7.2°C) WATER TEMPERATURE<br>DIVE #1<br>NORMAL BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9** | | | | | | | | |
| DPV #4 | Net Thrust (Pounds) | 36 | 34 | 33 | 32 | 32* | 28 | 13 | 10.8 (72 min) |
| DPV #2 | | 37 | 34 | 33 | 31 | 29 | 22 | 11.1 (60 min) | |

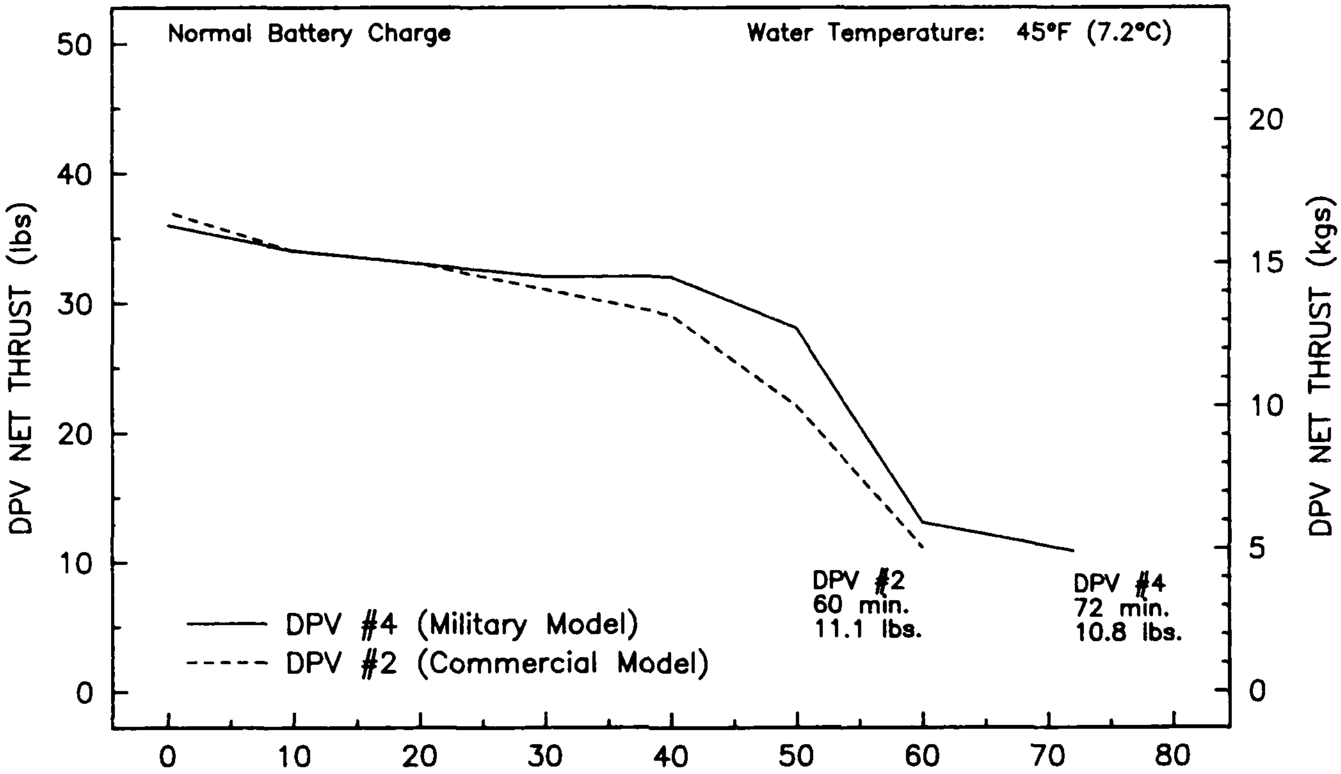
DPV #4 (Military Model) Duration to 30% Net Thrust: 72 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 60 Minutes

| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|---|---|
| | **DPV STATIC DURATION CHART, 45°F (7.2°C) WATER TEMPERATURE<br>DIVE #2<br>FAST BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9** | | | | | | | | |
| DPV #4 | Net Thrust (Pounds) | 37 | 35 | 34 | 33 | 32 | 30 | 18 | 11.1 (70 min) |
| DPV #2 | | 36 | 33 | 31 | 31 | 29 | 18 | 12 | 10.8 (61 min) |

DPV #4 (Military Model) Duration to 30% Net Thrust: 70 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 61 Minutes

TEKNA DIVER PROPULSION VEHICLE NET THRUST vs TIME

Unmanned Static Test. Propeller Pitch Setting 9.
Duration to 30% of Starting Net Thrust.



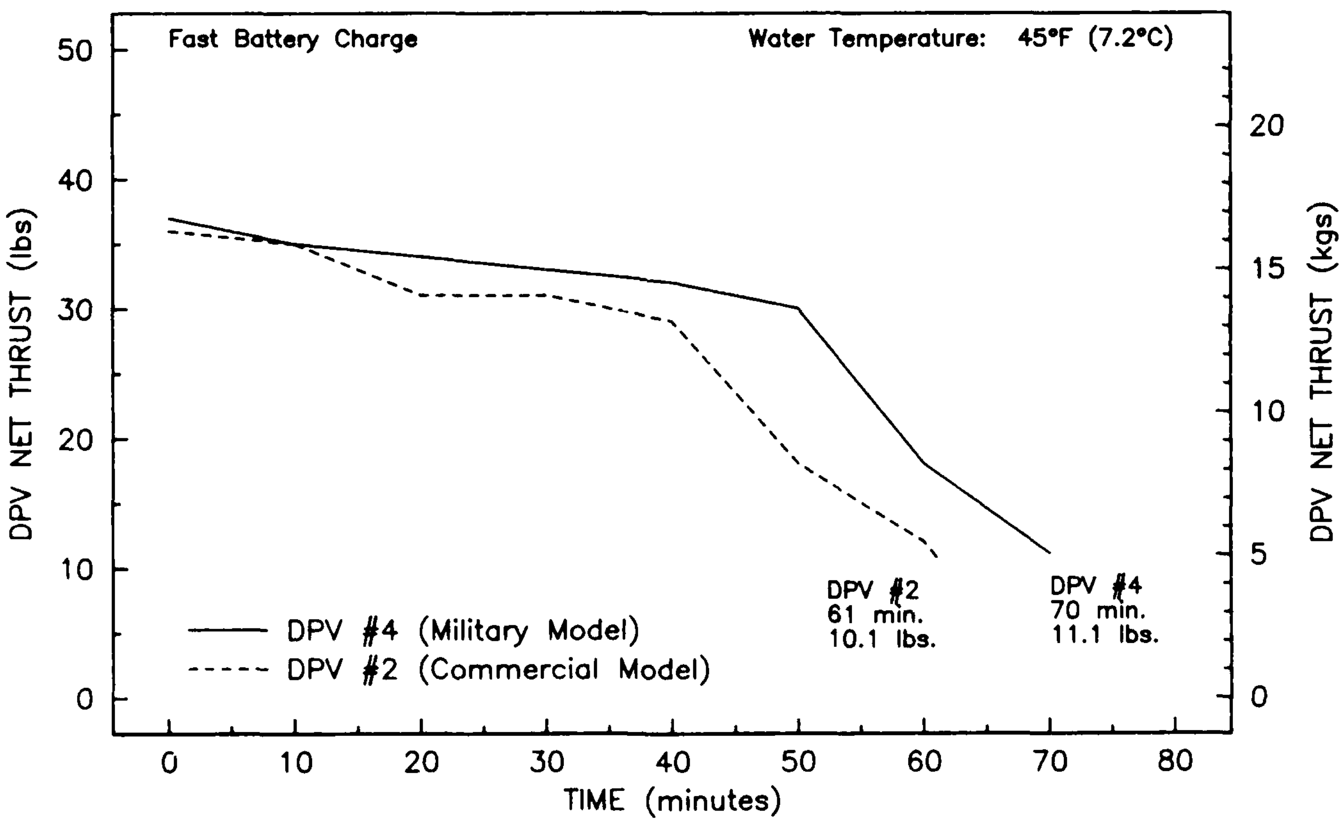



Figure A5

| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|---|---|
| | DPV STATIC DURATION CHART, 50°F (10°C) WATER TEMPERATURE<br>DIVE #1<br>NORMAL BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
| DPV #4 | Net Thrust (Pounds) | 38 | 36 | 35 | 33 | 32 | 30 | 15 | 11.4 (68 min) |
| DPV #2 | | 36 | 34 | 34 | 32 | 29 | 19 | 10.8 (58 min) | |

DPV #4 (Military Model) Duration to 30% Net Thrust: 68 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 58 Minutes

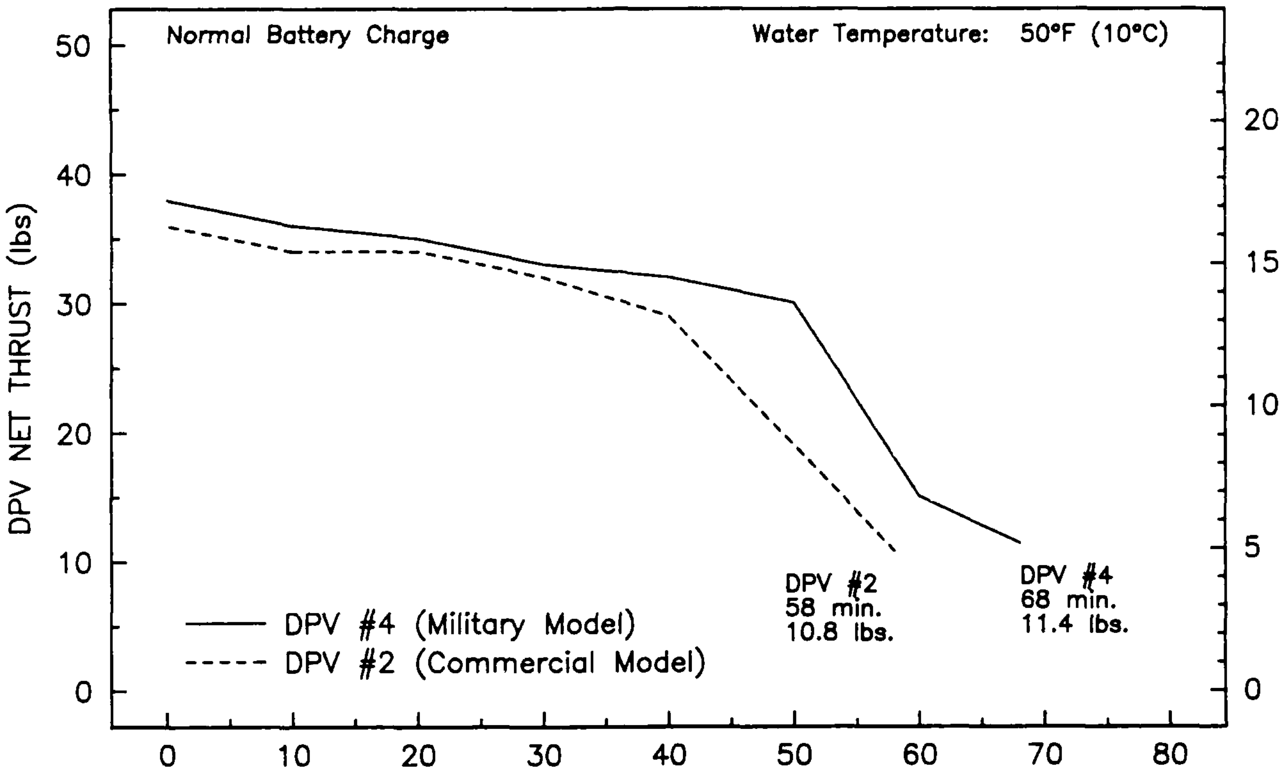
| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|---|---|
| | DPV STATIC DURATION CHART, 50°F (10°C) WATER TEMPERATURE<br>DIVE #2<br>FAST BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
| DPV #4 | Net Thrust (Pounds) | 37 | 36 | 34 | 32 | 32 | 29 | 16 | 11.1 (68 min) |
| DPV #2 | | 38 | 34 | 33 | 31 | 29 | 14 | 11.4 (58 min) | |

DPV #4 (Military Model) Duration to 30% Net Thrust: 68 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 58 Minutes

TEKNA DIVER PROPULSION VEHICLE NET THRUST vs TIME

Unmanned Static Test. Propeller Pitch Setting 9.

Duration to 30% of Starting Net Thrust.



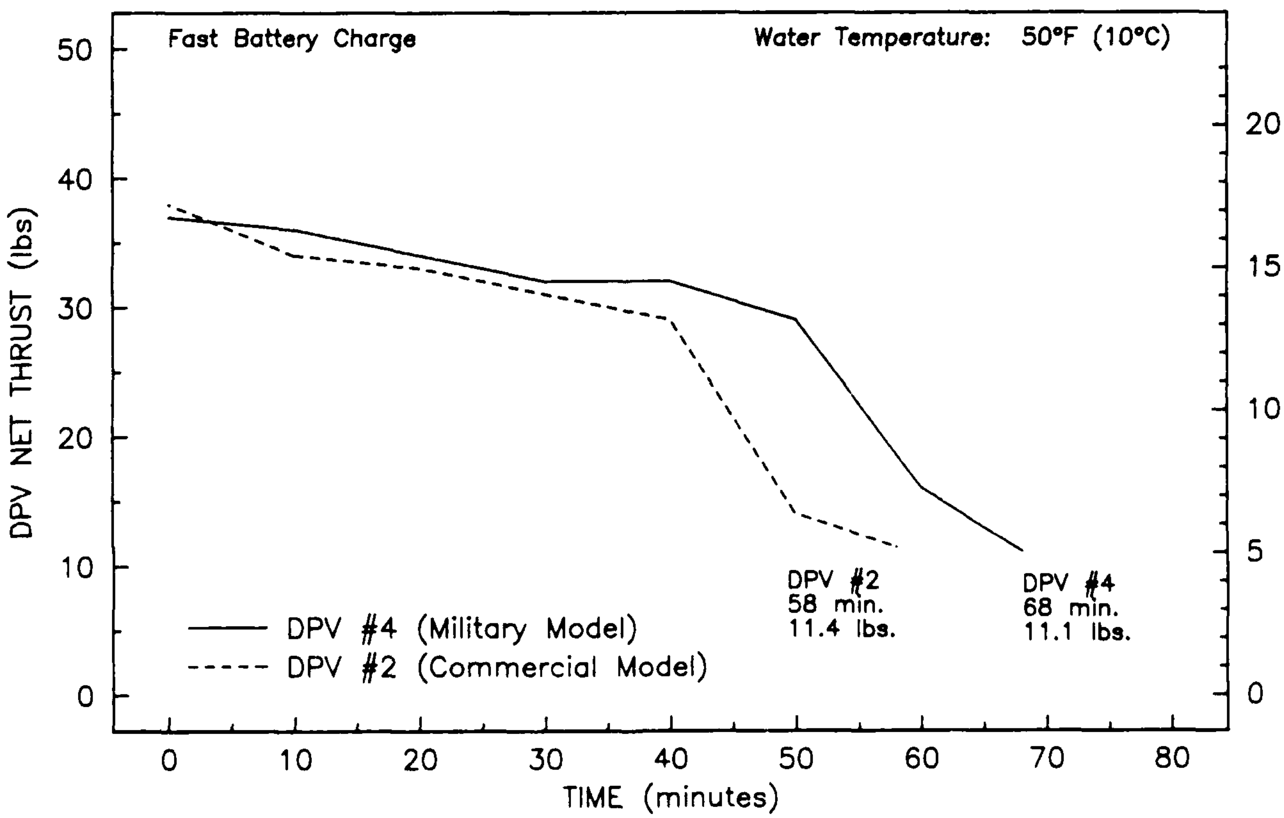



Figure A7

| | DPV STATIC DURATION CHART, 55°F (12.8°C) WATER TEMPERATURE<br>DIVE #1<br>NORMAL BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
| DPV #4 | Net Thrust (Pounds) | 36 | 36 | 34 | 34 | 31 | 28 | 16 | 10.8 (68 min) |
| DPV #2 | | 36 | 35 | 33 | 32 | 29 | 18 | 10.8 (58 min) | |

DPV #4 (Military Model) Duration to 30% Net Thrust: 68 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 58 Minutes

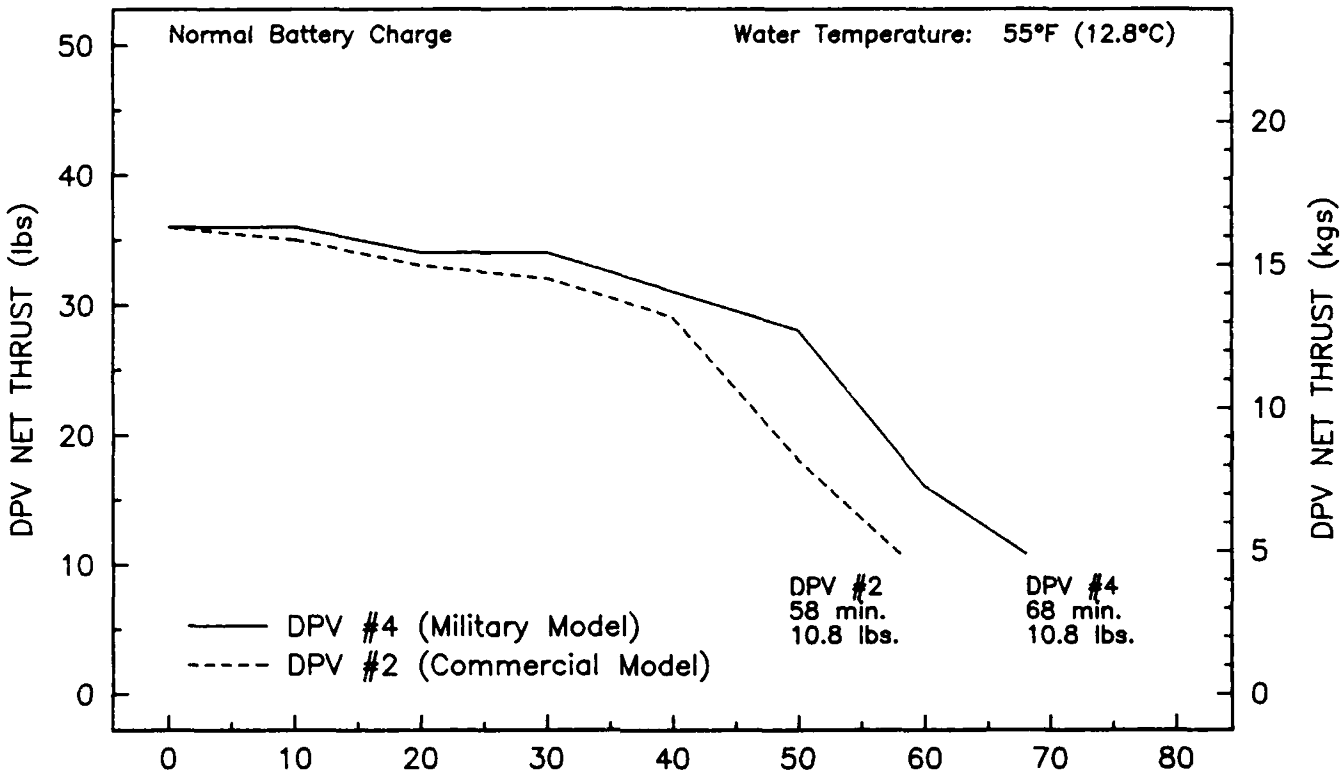
| | DPV STATIC DURATION CHART, 55°F (12.8°C) WATER TEMPERATURE<br>DIVE #2<br>FAST BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
| DPV #4 | Net Thrust (Pounds) | 39 | 36 | 36 | 34 | 33 | 31 | 17 | 11.7 (67 min) |
| DPV #2 | | 38 | 35 | 33 | 30 | 30 | 18 | 11.4 (58 min) | |

DPV #4 (Military Model) Duration to 30% Net Thrust: 67 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 58 Minutes

## TEKNA DIVER PROPULSION VEHICLE NET THRUST vs TIME

Unmanned Static Test. Propeller Pitch Setting 9.

Duration to 30% of Starting Net Thrust.



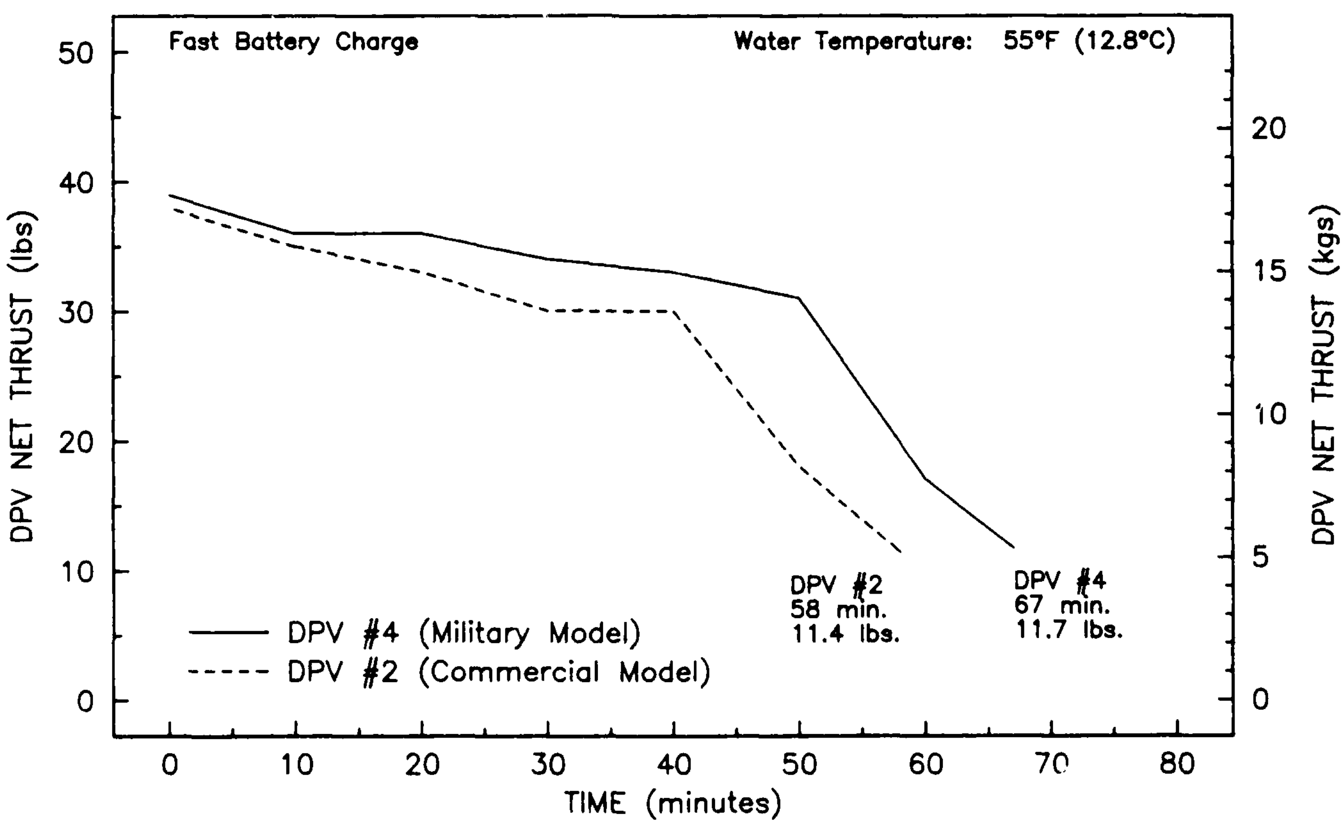



Figure A9

| | DPV STATIC DURATION CHART, 60°F (15.6°C) WATER TEMPERATURE<br>DIVE #1<br>NORMAL BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
| DPV #4 | Net Thrust (Pounds) | 38 | 36 | 33 | 33 | 31 | 26 | 14 | 11.4 (65 min) |
| DPV #2 | | 36 | 33 | 32 | 31 | 28 | 19 | 10.8 (59 min) | |

DPV #4 (Military Model) Duration to 30% Net Thrust: 65 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 59 Minutes

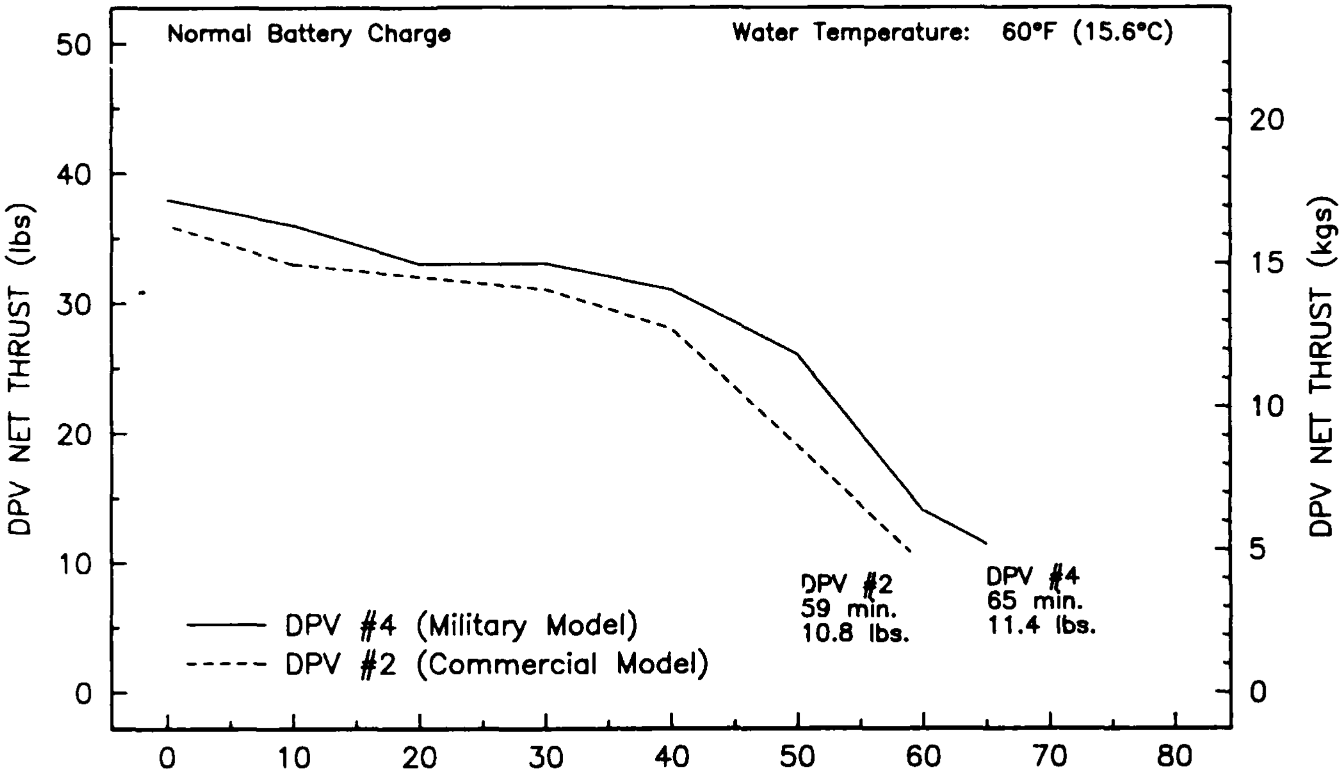
| | DPV STATIC DURATION CHART, 60°F (15.6°C) WATER TEMPERATURE<br>DIVE #2<br>FAST BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
| DPV #4 | Net Thrust (Pounds) | 42 | 40 | 39 | 38 | 35 | 32 | 21 | 12.6 (70 min) |
| DPV #2 | | 37 | 35 | 33 | 32 | 28 | 19 | 15 | 11.1 (66 min) |

DPV #4 (Military Model) Duration to 30% Net Thrust: 70 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 66 Minutes

TEKNA DIVER PROPULSION VEHICLE NET THRUST vs TIME

Unmanned Static Test. Propeller Pitch Setting 9.

Duration to 30% of Starting Net Thrust.



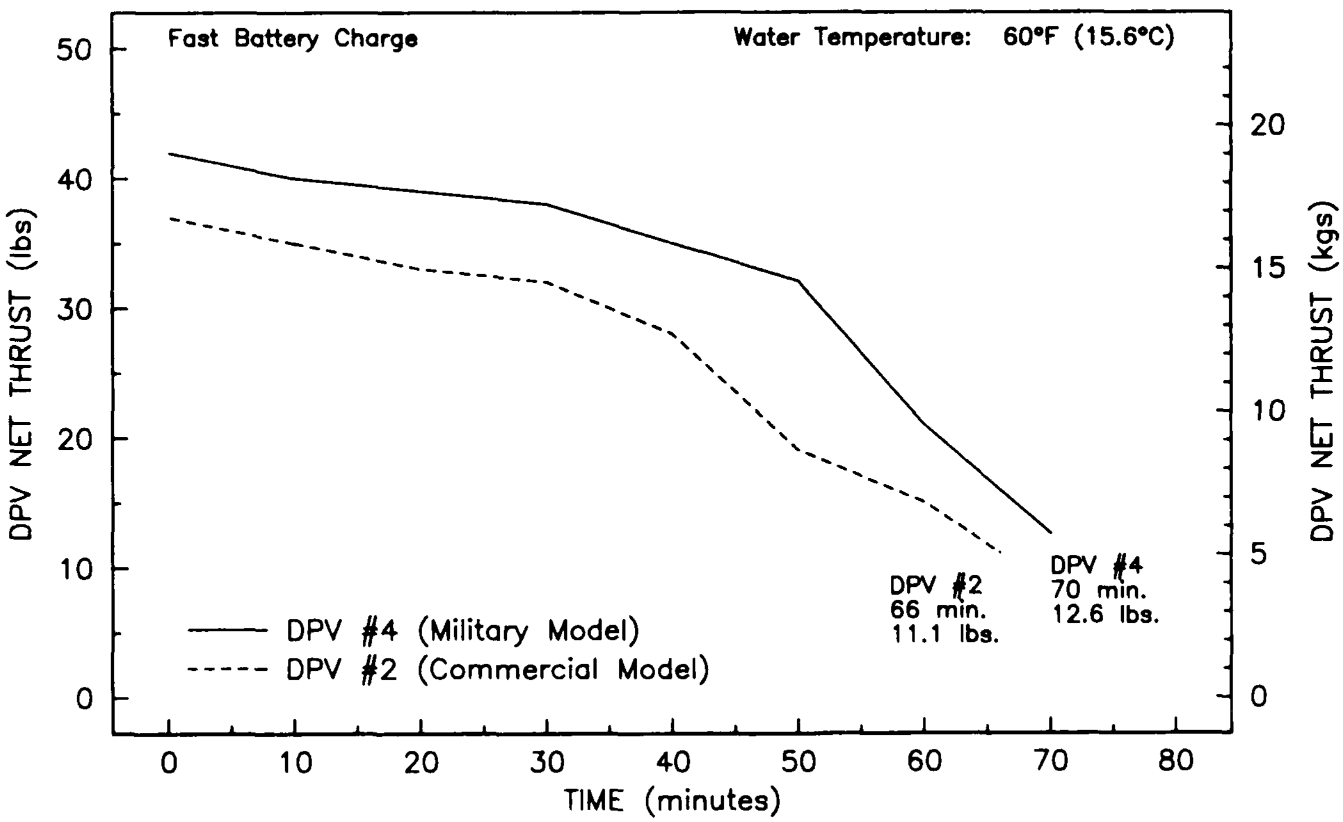



Figure A11

| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|---|---|
| | DPV STATIC DURATION CHART, 65°F (18.3°C) WATER TEMPERATURE<br>DIVE #1<br>NORMAL BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
| DPV #4 | Net Thrust (Pounds) | 37 | 36 | 34 | 33 | 32 | 29 | 16 | 11.1 (66 min) |
| DPV #2 | | 38 | 35 | 34 | 33 | 31 | 29 | 13 | 11.4 (61 min) |

DPV #4 (Military Model) Duration to 30% Net Thrust: 66 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 61 Minutes

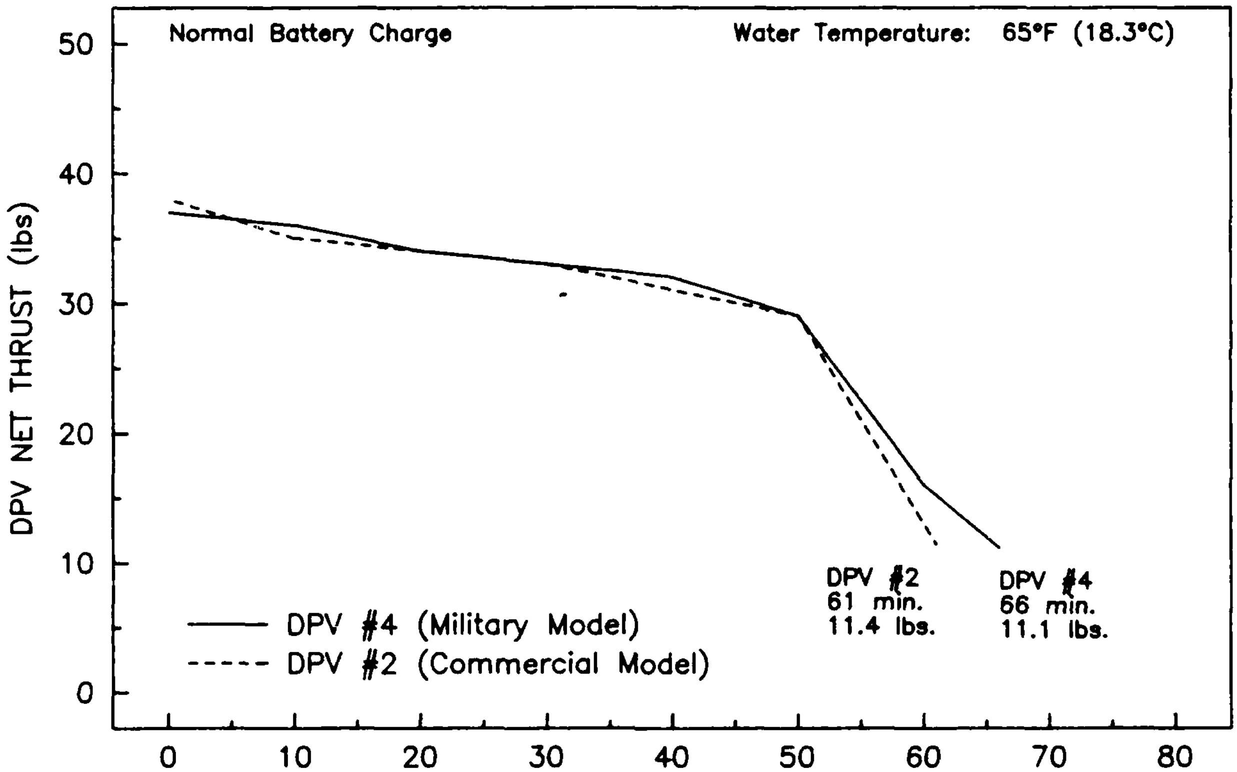
| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|---|---|
| | DPV STATIC DURATION CHART, 65°F (18.3°C) WATER TEMPERATURE<br>DIVE #2<br>FAST BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
| DPV #4 | Net Thrust (Pounds) | 39 | 37 | 35 | 34 | 32 | 31 | 21 | 11.7 (69 min) |
| DPV #2 | | 37 | 35 | 34 | 31 | 30 | 19 | 11.1 (59 min) | |

DPV #4 (Military Model) Duration to 30% Net Thrust: 69 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 59 Minutes

TEKNA DIVER PROPULSION VEHICLE NET THRUST vs TIME

Unmanned Static Test. Propeller Pitch Setting 9.

Duration to 30% of Starting Net Thrust.



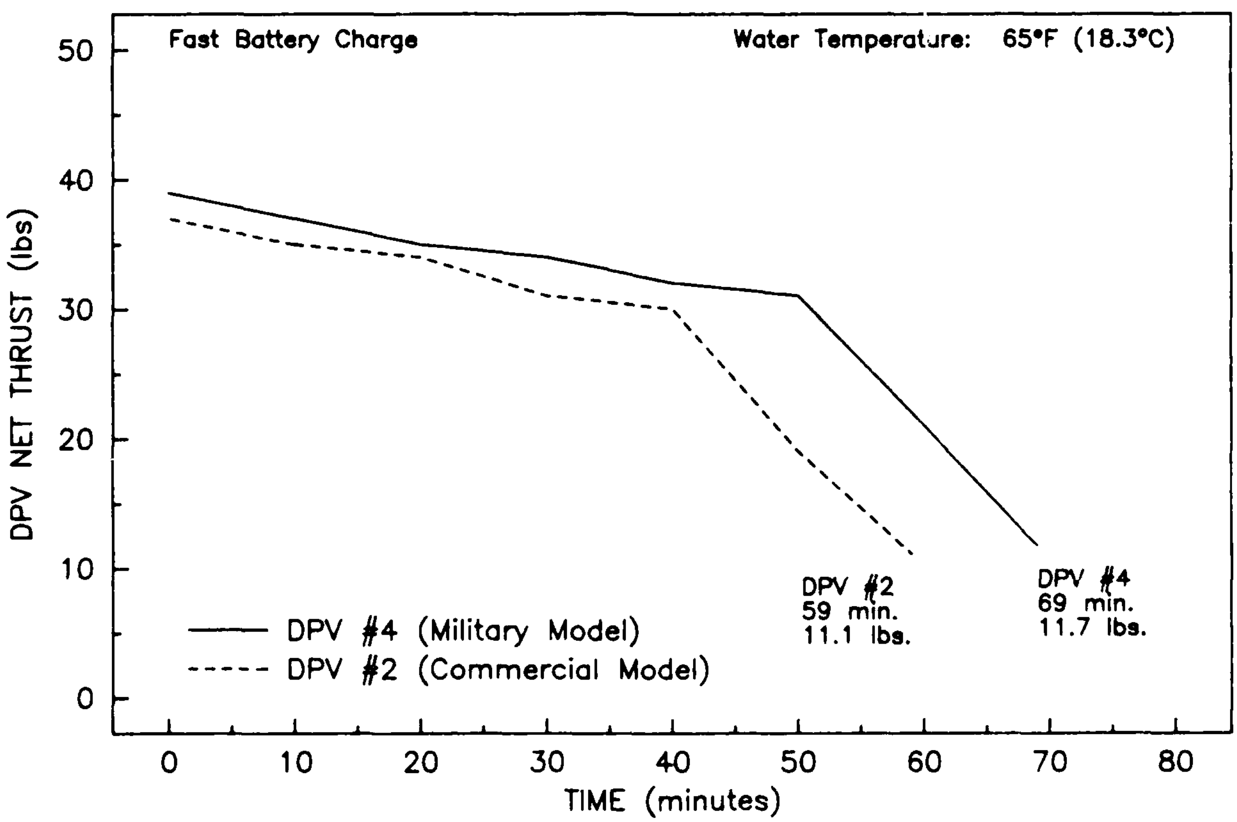



Figure A13

| | DPV STATIC DURATION CHART, 70°F (21.1°C) WATER TEMPERATURE<br>DIVE #1<br>NORMAL BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
| DPV #4 | Net Thrust (Pounds) | 38 | 35 | 34 | 34 | 33 | 30 | 16 | 11.4 (67 min) |
| DPV #2 | | 36 | 33 | 33 | 32 | 31 | 24 | 12 | 10.8 (62 min) |

DPV #4 (Military Model) Duration to 30% Net Thrust: 67 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 62 Minutes

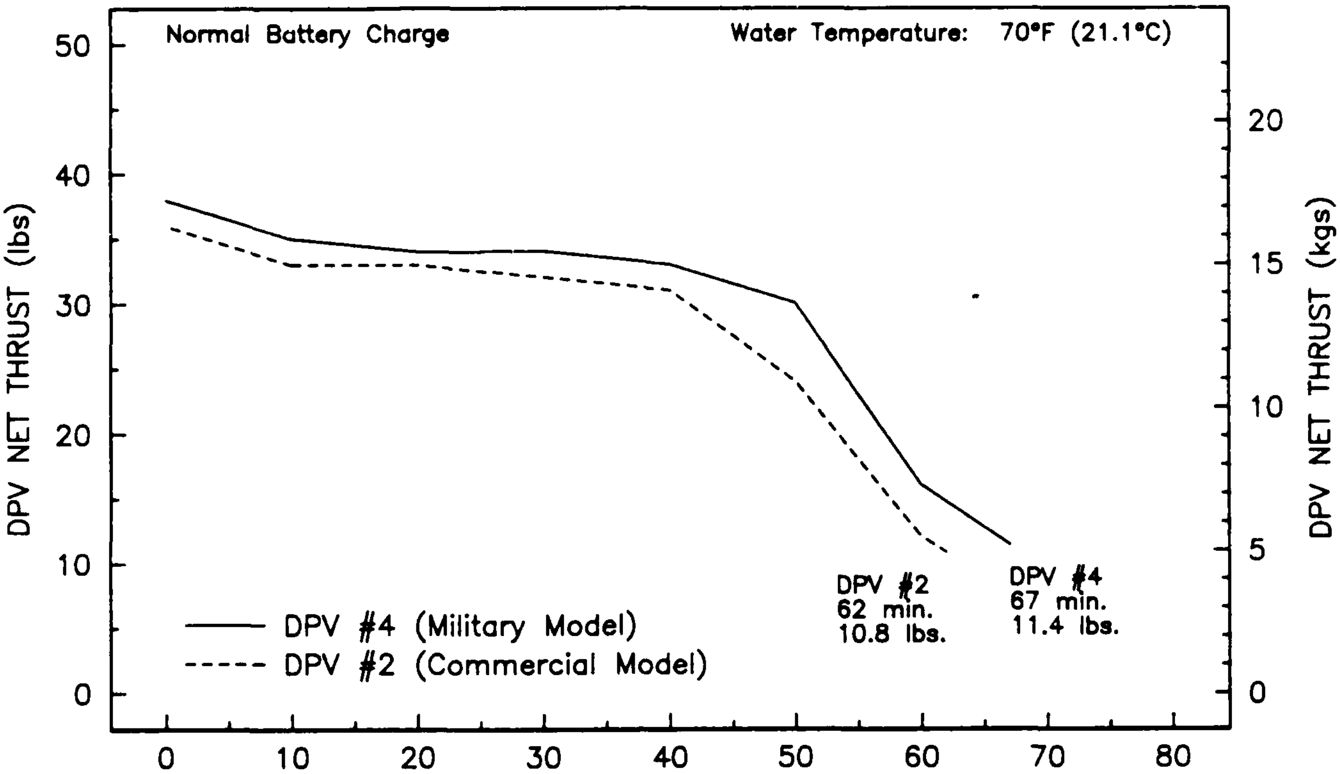
| | DPV STATIC DURATION CHART, 70°F (21.1°C) WATER TEMPERATURE<br>DIVE #2<br>FAST BATTERY CHARGE CYCLE<br>PROPELLOR PITCH SETTING 9 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Time (Minutes) | Start | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
| DPV #4 | Net Thrust (Pounds) | 38 | 37 | 36 | 34 | 33 | 32 | 23 | 11.4 (69 min) |
| DPV #2 | | 36 | 34 | 34 | 32 | 30 | 18 | 12 | 10.8 (61 min) |

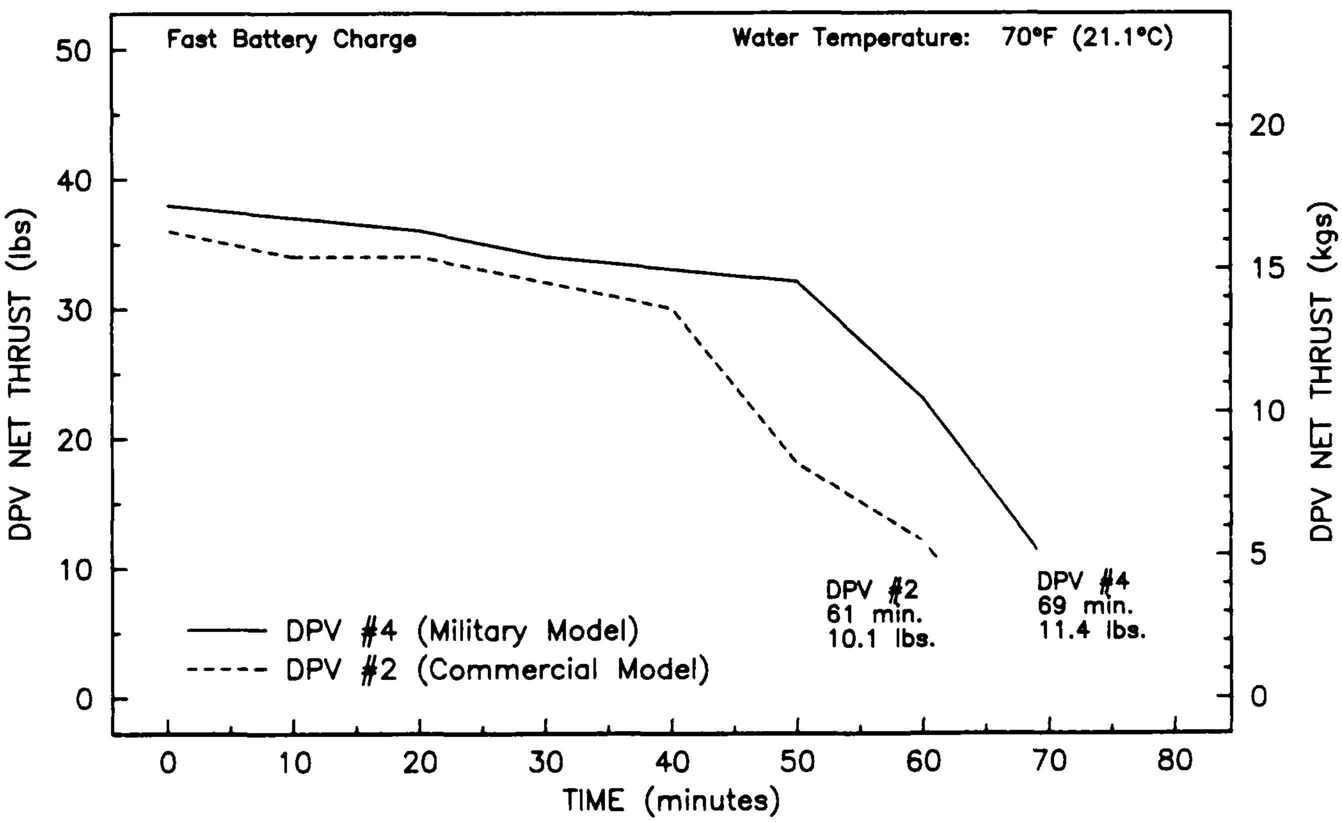
DPV #4 (Military Model) Duration to 30% Net Thrust: 69 Minutes
DPV #2 (Commercial Model) Duration to 30% Net Thrust: 61 Minutes

TEKNA DIVER PROPULSION VEHICLE NET THRUST vs TIME

Unmanned Static Test. Propeller Pitch Setting 9.

Duration to 30% of Starting Net Thrust.



APPENDIX B

DPV OPEN WATER TIME/DISTANCE DATA

Elapsed times, 200 yard times, average speed, and total distance traveled are charted. Approximate depth was 8 FSW. Approximate water temperature was 76°F.

KEY:

Figure B1

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #1 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 9, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 5 min 20 sec | 5 min 20 sec | 1.1 |
| 2 | 10 min 20 sec | 5 min | 1.2 |
| 3 | 14 min 20 sec | 4 min | 1.5 |
| 4 | 17 min 50 sec | 3 min 30 sec | 1.7 |
| 5 | 23 min | 5 min 10 sec | 1.2 |
| 6 | 28 min 20 sec | 5 min 20 sec | 1.3 |
| 7 | 32 min 20 sec | 4 min | 1.5 |
| 8 | 36 min 20 sec | 4 min | 1.5 |
| 9 | 40 min 20 sec | 4 min | 1.5 |
| 10 | 44 min 15 sec | 3 min 55 sec | 1.5 |
| 11 | 48 min 50 sec | 4 min 35 sec | 1.3 |
| 12 | 53 min 50 sec | 5 min | 1.2 |
| 13 | 57 min 55 sec | 4 min 5 sec | 1.5 |
| 14 | 62 min 20 sec | 4 min 25 sec | 1.4 |
| 15 | 67 min 20 sec | 5 min | 1.2 |

15 laps = total 3000 yds in 67 min 20 sec
Average Speed = 1.5 knots

Figure B2

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #2 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 9, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 4 min | 4 min | 1.5 |
| 2 | 8 min | 4 min | 1.5 |
| 3 | 12 min 30 sec | 3 min 30 sec | 1.7 |
| 4 | 16 min 15 sec | 3 min 45 sec | 1.6 |
| 5 | 19 min 40 sec | 3 min 25 sec | 1.8 |
| 6 | 23 min 15 sec | 3 min 35 sec | 1.7 |
| 7 | 26 min 50 sec | 3 min 25 sec | 1.7 |
| 8 | 30 min 40 sec | 3 min 50 sec | 1.6 |
| 9 | 34 min 40 sec | 4 min | 1.5 |
| 10 | 38 min 35 sec | 3 min 55 sec | 1.5 |
| 11 | 42 min 30 sec | 3 min 55 sec | 1.5 |
| 12 | 45 min 40 sec | 3 min 10 sec | 1.9 |
| 13 | 51 min 5 sec | 5 min 25 sec | 1.1 |
| 14 | 56 min | 4 min 55 sec | 1.2 |
| 15 | 61 min 10 sec | 5 min 10 sec | 1.2 |
| 16 | 66 min 30 sec | 5 min 20 sec | 1.1 |

16 laps = total 3200 yds in 66 min 30 sec
Average Speed = 1.5 knots

Figure B3

OPEN WATER TIME/DISTANCE TRIAL
DPV #3 (MILITARY MODEL)
PROPELLOR PITCH SETTING 9, RESTING DIVER

| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
|---|---|---|---|
| 1 | 3 min 8 sec | 3 min 8 sec | 1.9 |
| 2 | 6 min 40 sec | 3 min 34 sec | 1.7 |
| 3 | 10 min | 3 min 20 sec | 1.8 |
| 4 | 14 min 5 sec | 4 min 5 sec | 1.5 |
| 5 | 18 min 30 sec | 4 min 25 sec | 1.4 |
| 6 | 22 min 45 sec | 4 min 15 sec | 1.4 |
| 7 | 27 min 15 sec | 4 min 30 sec | 1.3 |
| 8 | 32 min 20 sec | 5 min 5 sec | 1.2 |
| 9 | 37 min 40 sec | 5 min 20 sec | 1.1 |
| 10 | 43 min 25 sec | 5 min 48 sec | 1.0 |
| 11 | 49 min 25 sec | 6 min | 1.0 |
| 12 | 55 min 40 sec | 6 min 15 sec | 1.0 |

12 laps = total 2400 yds in 55 min 40 sec
Average Speed = 1.4 knots

Figure B4

OPEN WATER TIME/DISTANCE TRIAL
DPV #4 (MILITARY MODEL)
PROPELLOR PITCH SETTING 9, RESTING DIVER

| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
|---|---|---|---|
| 1 | 3 min 30 sec | 3 min 30 sec | 1.7 |
| 2 | 6 min 54 sec | 3 min 24 sec | 1.7 |
| 3 | 11 min 4 sec | 4 min 10 sec | 1.2 |
| 4 | 14 min 35 sec | 3 min 31 sec | 1.7 |
| 5 | 18 min 3 sec | 5 min 28 sec | 1.1 |
| 6 | 21 min 19 sec | 3 min 16 sec | 1.8 |
| 7 | 24 min 34 sec | 3 min 15 sec | 1.9 |
| 8 | 28 min 27 sec | 3 min 53 sec | 1.6 |
| 9 | 31 min 58 sec | 3 min 31 sec | 1.7 |
| 10 | 35 min 36 sec | 3 min 38 sec | 1.7 |
| 11 | 39 min 12 sec | 3 min 36 sec | 1.7 |
| 12 | 43 min | 3 min 48 sec | 1.6 |
| 13 | 47 min 50 sec | 4 min 50 sec | 1.2 |
| 14 | 53 min 30 sec | 5 min 40 sec | 1.1 |
| 15 | 60 min | 6 min 30 sec | .9 |
| 16 | 67 min 22 sec | 7 min 22 sec | .8 |

16 laps = total 3200 yds in 67 min 22 sec
Average Speed = 1.5 knots

Figure B5

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #1 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 9, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 15 sec | 3 min 15 sec | 1.9 |
| 2 | 6 min 46 sec | 3 min 31 sec | 1.7 |
| 3 | 10 min 12 sec | 3 min 26 sec | 1.8 |
| 4 | 13 min 38 sec | 3 min 26 sec | 1.8 |
| 5 | 17 min | 3 min 22 sec | 1.8 |
| 6 | 20 min 30 sec | 3 min 30 sec | 1.7 |
| 7 | 24 min | 3 min 30 sec | 1.7 |
| 8 | 27 min 30 sec | 3 min 30 sec | 1.7 |
| 9 | 31 min | 3 min 30 sec | 1.7 |
| 10 | 34 min 40 sec | 3 min 40 sec | 1.6 |
| 11 | 38 min 15 sec | 3 min 35 sec | 1.7 |
| 12 | 41 min 55 sec | 3 min 40 sec | 1.6 |
| 13 | 45 min 35 sec | 3 min 40 sec | 1.6 |
| 14 | 49 min 29 sec | 3 min 54 sec | 1.5 |
| 15 | 55 min 15 sec | 5 min 46 sec | 1.0 |

15 laps = total 3000 yds in 55 min 15 sec
Average Speed = 1.6 knots

Figure B6

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #2 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 9, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 15 sec | 3 min 15 sec | 1.9 |
| 2 | 6 min 55 sec | 3 min 40 sec | 1.6 |
| 3 | 10 min 35 sec | 3 min 40 sec | 1.6 |
| 4 | 14 min | 3 min 25 sec | 1.8 |
| 5 | 17 min 30 sec | 3 min 30 sec | 1.7 |
| 6 | 21 min 20 sec | 3 min 50 sec | 1.6 |
| 7 | 24 min 45 sec | 3 min 25 sec | 1.8 |
| 8 | 28 min 10 sec | 3 min 25 sec | 1.8 |
| 9 | 31 min 45 sec | 3 min 35 sec | 1.7 |
| 10 | 35 min 30 sec | 3 min 45 sec | 1.6 |
| 11 | 39 min 25 sec | 3 min 55 sec | 1.5 |
| 12 | 43 min 50 sec | 4 min 25 sec | 1.4 |
| 13 | 49 min 10 sec | 5 min 20 sec | 1.1 |
| 14 | 53 min 20 sec | 4 min 10 sec | 1.4 |
| 15 | 57 min 40 sec | 4 min 20 sec | 1.4 |
| 16 | 61 min 40 sec | 4 min | 1.5 |

16 laps = total 3200 yds in 61 min 40 sec
Average Speed = 1.6 knots

Figure B7

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #3 (MILITARY MODEL)<br>PROPELLOR PITCH SETTING 9, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min | 3 min | 2.0 |
| 2 | 6 min 6 sec | 3 min 6 sec | 1.9 |
| 3 | 9 min 9 sec | 3 min 3 sec | 2.0 |
| 4 | 12 min 24 sec | 3 min 15 sec | 1.9 |
| 5 | 15 min 34 sec | 3 min 10 sec | 1.9 |
| 6 | 18 min 54 sec | 3 min 20 sec | 1.8 |
| 7 | 22 min 15 sec | 3 min 21 sec | 1.8 |
| 8 | 25 min 45 sec | 3 min 30 sec | 1.7 |
| 9 | 29 min 9 sec | 3 min 24 sec | 1.8 |
| 10 | 32 min 30 sec | 3 min 21 sec | 1.8 |
| 11 | 35 min 58 sec | 3 min 28 sec | 1.3 |
| 12 | 39 min 34 sec | 3 min 36 sec | 1.7 |
| 13 | 43 min 4 sec | 3 min 30 sec | 1.7 |
| 14 | 48 min 25 sec | 5 min 21 sec | 1.1 |

14 laps = total 2800 yds in 48 min 25 sec
Average Speed = 1.7 knots

Figure B8

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #4 (MILITARY MODEL)<br>PROPELLOR PITCH SETTING 9, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 4 min 20 sec | 4 min 20 sec | 1.4 |
| 2 | 7 min 30 sec | 3 min 10 sec | 1.9 |
| 3 | 10 min 40 sec | 3 min 10 sec | 1.9 |
| 4 | 14 min | 3 min 20 sec | 1.8 |
| 5 | 17 min 8 sec | 3 min 8 sec | 1.9 |
| 6 | 20 min 26 sec | 3 min 18 sec | 1.8 |
| 7 | 23 min 44 sec | 3 min 18 sec | 1.8 |
| 8 | 27 min 4 sec | 3 min 20 sec | 1.8 |
| 9 | 30 min 22 sec | 3 min 18 sec | 1.8 |
| 10 | 33 min 47 sec | 3 min 25 sec | 1.8 |
| 11 | 37 min 12 sec | 3 min 25 sec | 1.8 |
| 12 | 40 min 46 sec | 3 min 34 sec | 1.7 |
| 13 | 44 min 58 sec | 4 min 12 sec | 1.4 |
| 14 | 50 min 12 sec | 5 min 14 sec | 1.2 |

14 laps = total 2800 yds in 50 min 12 sec
Average Speed = 1.7 knots

Figure B9

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #1 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 9, SWIMMING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 2 min 50 sec | 2 min 50 sec | 2.1 |
| 2 | 5 min 50 sec | 3 min | 2.0 |
| 3 | 6 min 50 sec | 3 min | 2.0 |
| 4 | 11 min 55 sec | 3 min 5 sec | 2.0 |
| 5 | 15 min | 3 min 5 sec | 2.0 |
| 6 | 18 min 5 sec | 3 min 5 sec | 2.0 |
| 7 | 21 min 10 sec | 3 min 5 sec | 2.0 |
| 8 | 24 min 15 sec | 3 min 5 sec | 2.0 |
| 9 | 27 min 20 sec | 3 min 5 sec | 2.0 |
| 10 | 30 min 25 sec | 3 min 5 sec | 2.0 |
| 11 | 33 min 35 sec | 3 min 10 sec | 1.9 |
| 12 | 36 min 45 sec | 3 min 10 sec | 1.9 |
| 13 | 40 min | 3 min 15 sec | 1.8 |
| 14 | 43 min 14 sec | 3 min 15 sec | 1.8 |
| 15 | 46 min 50 sec | 3 min 35 sec | 1.7 |
| 16 | 51 min 5 sec | 4 min 15 sec | 1.4 |

16 laps = total 3200 yds in 51 min 05 sec
Average Speed = 1.9 knots

Figure B10

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #2 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 9, SWIMMING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 45 sec | 3 min 45 sec | 1.6 |
| 2 | 7 min 10 sec | 3 min 25 sec | 1.7 |
| 3 | 10 min 30 sec | 3 min 20 sec | 1.8 |
| 4 | 13 min 55 sec | 3 min 25 sec | 1.8 |
| 5 | 17 min 25 sec | 3 min 30 sec | 1.7 |
| 6 | 20 min 45 sec | 3 min 20 sec | 1.8 |
| 7 | 24 min 15 sec | 3 min 30 sec | 1.7 |
| 8 | 27 min 50 sec | 3 min 35 sec | 1.7 |
| 9 | 31 min 20 sec | 3 min 30 sec | 1.7 |
| 10 | 34 min 50 sec | 3 min 30 sec | 1.7 |
| 11 | 38 min 25 sec | 3 min 35 sec | 1.7 |
| 12 | 42 min 5 sec | 3 min 40 sec | 1.6 |
| 13 | 45 min 55 sec | 3 min 50 sec | 1.6 |
| 14 | 49 min 45 sec | 3 min 50 sec | 1.6 |
| 15 | 53 min 10 sec | 3 min 25 sec | 1.8 |
| 16 | 56 min 45 sec | 3 min 35 sec | 1.7 |
| 17 | 61 min 10 sec | 4 min 25 sec | 1.4 |
| 18 | 65 min 10 sec | 4 min | 1.5 |

18 laps = total 3600 yds in 65 min 10 sec
Average Speed = 1.7 knots

Figure B11

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #3 (MILITARY MODEL)<br>PROPELLOR PITCH SETTING 9, SWIMMING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 2 min 50 sec | 2 min 50 sec | 2.1 |
| 2 | 5 min 45 sec | 2 min 55 sec | 2.0 |
| 3 | 8 min 40 sec | 2 min 55 sec | 2.0 |
| 4 | 11 min 36 sec | 2 min 56 sec | 2.0 |
| 5 | 14 min 35 sec | 2 min 59 sec | 2.0 |
| 6 | 17 min 40 sec | 3 min 5 sec | 1.9 |
| 7 | 20 min 41 sec | 3 min 1 sec | 2.0 |
| 8 | 23 min 41 sec | 3 min | 2.0 |
| 9 | 26 min 47 sec | 3 min 6 sec | 1.9 |
| 10 | 29 min 59 sec | 3 min 12 sec | 1.9 |
| 11 | 33 min 11 sec | 3 min 12 sec | 1.9 |
| 12 | 36 min 41 sec | 3 min 20 sec | 1.8 |
| 13 | 40 min 19 sec | 3 min 48 sec | 1.6 |
| 14 | 44 min 44 sec | 4 min 25 sec | 1.4 |
| 15 | 49 min 49 sec | 5 min 5 sec | 1.2 |

15 laps = total 3000 yds in 49 min 49 sec
Average Speed = 1.8 knots

Figure B12

OPEN WATER TIME/DISTANCE TRIAL
DPV #4 (MILITARY MODEL)
PROPELLOR PITCH SETTING 9, SWIMMING DIVER

| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
|---|---|---|---|
| 1 | 3 min 10 sec | 3 min 10 sec | 1.9 |
| 2 | 6 min | 3 min | 2.0 |
| 3 | 9 min | 3 min | 2.0 |
| 4 | 11 min 57 sec | 2 min 57 sec | 2.0 |
| 5 | 14 min 58 sec | 3 min 1 sec | 2.0 |
| 6 | 17 min 58 sec | 3 min | 2.0 |
| 7 | 21 min | 3 min 2 sec | 2.0 |
| 8 | 24 min 3 sec | 3 min 3 sec | 2.0 |
| 9 | 27 min 6 sec | 3 min 3 sec | 2.0 |
| 10 | 30 min 9 sec | 3 min 3 sec | 2.0 |
| 11 | 33 min 12 sec | 3 min 3 sec | 2.0 |
| 12 | 36 min 34 sec | 3 min 22 sec | 1.8 |
| 13 | 34 min 49 sec | 3 min 15 sec | 1.8 |
| 14 | 43 min 22 sec | 3 min 43 sec | 1.6 |
| 15 | 47 min 10 sec | 3 min 48 sec | 1.6 |

15 laps = total 3000 yds in 47 min 10 sec
Average Speed = 1.9 knots

Figure B13

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #1 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 6, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 4 min 35 sec | 4 min 35 sec | 1.3 |
| 2 | 9 min 55 sec | 5 min 20 sec | 1.1 |
| 3 | 15 min 20 sec | 5 min 25 sec | 1.1 |
| 4 | 20 min 20 sec | 5 min | 1.2 |
| 5 | 25 min 25 sec | 5 min 5 sec | 1.2 |
| 6 | 30 min 40 sec | 5 min 15 sec | 1.1 |
| 7 | 36 min 15 sec | 5 min 35 sec | 1.1 |
| 8 | 47 min 5 sec | 5 min 50 sec | 1.0 |
| 9 | 48 min 15 sec | 6 min 10 sec | 1.0 |
| 10 | 53 min 20 sec | 5 min 5 sec | 1.2 |
| 11 | 58 min | 4 min 40 sec | 1.3 |
| 12 | 62 min 45 sec | 4 min 45 sec | 1.3 |
| 13 | 67 min 20 sec | 4 min 35 sec | 1.3 |
| 14 | 72 min 25 sec | 5 min 5 sec | 1.2 |
| 15 | 77 min 35 sec | 5 min 10 sec | 1.2 |
| 16 | 83 min | 5 min 25 sec | 1.1 |
| 17 | 88 min 35 sec | 5 min 35 sec | 1.1 |

17 laps = total 3400 yds in 88 min 35 sec
Average Speed = 1.2 knots

Figure B14

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #2 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 6, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 45 sec | 3 min 45 sec | 1.6 |
| 2 | 8 min 15 sec | 4 min 30 sec | 1.3 |
| 3 | 12 min 30 sec | 4 min 15 sec | 1.4 |
| 4 | 16 min 35 sec | 4 min 5 sec | 1.2 |
| 5 | 20 min 45 sec | 4 min 10 sec | 1.5 |
| 6 | 25 min 5 sec | 4 min 20 sec | 1.4 |
| 7 | 29 min 20 sec | 3 min 55 sec | 1.5 |
| 8 | 34 min 35 sec | 4 min 45 sec | 1.3 |
| 9 | 38 min 40 sec | 4 min 5 sec | 1.2 |
| 10 | 42 min 45 sec | 3 min 55 sec | 1.5 |
| 11 | 47 min | 4 min 15 sec | 1.4 |
| 12 | 51 min 25 sec | 4 min 25 sec | 1.4 |
| 13 | 56 min 20 sec | 4 min 55 sec | 1.2 |
| 14 | 61 min 10 sec | 4 min 50 sec | 1.2 |
| 15 | 66 min 30 sec | 5 min 20 sec | 1.2 |

15 laps = total 3000 yds in 66 min 30 sec
Average Speed = 1.4 knots

Figure B15

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #3 (MILITARY MODEL)<br>PROPELLOR PITCH SETTING 6, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 24 sec | 3 min 24 sec | 1.8 |
| 2 | 6 min 51 sec | 3 min 27 sec | 1.7 |
| 3 | 10 min 18 sec | 3 min 27 sec | 1.7 |
| 4 | 13 min 51 sec | 3 min 33 sec | 1.7 |
| 5 | 17 min 22 sec | 3 min 31 sec | 1.7 |
| 6 | 21 min 1 sec | 3 min 39 sec | 1.6 |
| 7 | 24 min 31 sec | 3 min 30 sec | 1.7 |
| 8 | 28 min 7 sec | 3 min 36 sec | 1.7 |
| 9 | 31 min 53 sec | 3 min 46 sec | 1.6 |
| 10 | 35 min 29 sec | 3 min 36 sec | 1.7 |
| 11 | 39 min | 3 min 31 sec | 1.7 |
| 12 | 42 min 35 sec | 3 min 35 sec | 1.7 |
| 13 | 47 min 15 sec | 3 min 40 sec | 1.6 |
| 14 | 51 min | 3 min 45 sec | 1.6 |
| 15 | 55 min 8 sec | 4 min 8 sec | 1.5 |
| 16 | 60 min 5 sec | 4 min 57 sec | 1.2 |

16 laps = total 3200 yds in 60 min 05 sec
Average Speed = 1.6 knots

Figure B16

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #4 (MILITARY MODEL)<br>PROPELLOR PITCH SETTING 6, RESTING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 21 sec | 3 min 21 sec | 1.8 |
| 2 | 6 min 39 sec | 3 min 18 sec | 1.8 |
| 3 | 5 min 59 sec | 3 min 20 sec | 1.8 |
| 4 | 13 min 19 sec | 3 min 20 sec | 1.8 |
| 5 | 16 min 37 sec | 3 min 18 sec | 1.8 |
| 6 | 19 min 55 sec | 3 min 18 sec | 1.8 |
| 7 | 23 min 16 sec | 3 min 21 sec | 1.8 |
| 8 | 26 min 46 sec | 3 min 30 sec | 1.7 |
| 9 | 30 min 21 sec | 3 min 25 sec | 1.8 |
| 10 | 33 min 48 sec | 3 min 27 sec | 1.7 |
| 11 | 37 min 20 sec | 3 min 32 sec | 1.7 |
| 12 | 41 min 2 sec | 3 min 42 sec | 1.6 |
| 13 | 44 min 44 sec | 3 min 42 sec | 1.6 |
| 14 | 48 min 32 sec | 3 min 48 sec | 1.6 |
| 15 | 53 min 24 sec | 3 min 52 sec | 1.6 |
| 16 | 57 min 18 sec | 3 min 54 sec | 1.5 |
| 17 | 61 min 30 sec | 4 min 12 sec | 1.4 |
| 18 | 66 min 15 sec | 4 min 45 sec | 1.3 |

18 laps = total 3600 yds in 66 min 15 sec
Average Speed = 1.7 knots

Figure B17

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #1 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 6, SWIMMING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 55 sec | 3 min 55 sec | 1.5 |
| 2 | 8 min | 4 min 5 sec | 1.5 |
| 3 | 12 min 5 sec | 4 min 5 sec | 1.5 |
| 4 | 16 min 15 sec | 4 min 10 sec | 1.4 |
| 5 | 20 min 20 sec | 4 min 5 sec | 1.5 |
| 6 | 24 min 40 sec | 4 min 10 sec | 1.4 |
| 7 | 28 min 50 sec | 4 min 10 sec | 1.4 |
| 8 | 33 min 10 sec | 4 min 20 sec | 1.4 |
| 9 | 37 min 25 sec | 4 min 15 sec | 1.4 |
| 10 | 41 min 50 sec | 4 min 25 sec | 1.4 |
| 11 | 46 min 70 sec | 4 min 30 sec | 1.3 |
| 12 | 51 min | 4 min 40 sec | 1.3 |
| 13 | 55 min 35 sec | 4 min 35 sec | 1.3 |
| 14 | 60 min 10 sec | 4 min 35 sec | 1.3 |
| 15 | 65 min 5 sec | 4 min 55 sec | 1.2 |
| 16 | 69 min 55 sec | 5 min 5 sec | 1.2 |
| 17 | 74 min 45 sec | 4 min 50 sec | 1.2 |

17 laps = total 3400 yds in 74 min 45 sec
Average Speed = 1.4 knots

Figure B18

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #2 (COMMERCIAL MODEL)<br>PROPELLOR PITCH SETTING 6, SWIMMING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 20 sec | 3 min 20 sec | 1.8 |
| 2 | 6 min 50 sec | 3 min 30 sec | 1.7 |
| 3 | 10 min 15 sec | 3 min 25 sec | 1.8 |
| 4 | 13 min 50 sec | 3 min 35 sec | 1.7 |
| 5 | 17 min 25 sec | 3 min 35 sec | 1.7 |
| 6 | 21 min 5 sec | 3 min 40 sec | 1.6 |
| 7 | 24 min 45 sec | 3 min 40 sec | 1.6 |
| 8 | 28 min 25 sec | 3 min 40 sec | 1.6 |
| 9 | 32 min 5 sec | 3 min 40 sec | 1.6 |
| 10 | 35 min 45 sec | 3 min 40 sec | 1.6 |
| 11 | 39 min 25 sec | 3 min 40 sec | 1.6 |
| 12 | 43 min 15 sec | 3 min 50 sec | 1.6 |
| 13 | 47 min 5 sec | 3 min 50 sec | 1.6 |
| 14 | 51 min | 3 min 55 sec | 1.5 |
| 15 | 55 min 5 sec | 4 min 5 sec | 1.5 |
| 16 | 59 min 15 sec | 4 min 10 sec | 1.4 |
| 17 | 63 min 25 sec | 4 min 10 sec | 1.4 |
| 18 | 67 min 45 sec | 4 min 20 sec | 1.4 |
| 19 | 72 min 15 sec | 4 min 30 sec | 1.3 |
| 20 | 76 min 55 sec | 4 min 45 sec | 1.3 |
| 21 | 81 min 50 sec | 4 min 55 sec | 1.2 |

21 laps = total 4200 yds in 81 min 50 sec
Average Speed = 1.5 knots

Figure B19

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #3 (MILITARY MODEL)<br>PROPELLOR PITCH SETTING 6, SWIMMING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 12 sec | 3 min 12 sec | 1.9 |
| 2 | 6 min 42 sec | 3 min 20 sec | 1.8 |
| 3 | 9 min 50 sec | 3 min 8 sec | 1.9 |
| 4 | 13 min 8 sec | 3 min 18 sec | 1.8 |
| 5 | 16 min 26 sec | 3 min 18 sec | 1.8 |
| 6 | 19 min 41 sec | 3 min 15 sec | 1.9 |
| 7 | 23 min 1 sec | 3 min 20 sec | 1.8 |
| 8 | 26 min 16 sec | 3 min 15 sec | 1.9 |
| 9 | 29 min 34 sec | 3 min 18 sec | 1.8 |
| 10 | 33 min 52 sec | 3 min 18 sec | 1.8 |
| 11 | 37 min 15 sec | 3 min 23 sec | 1.8 |
| 12 | 40 min 41 sec | 3 min 26 sec | 1.8 |
| 13 | 44 min 9 sec | 3 min 28 sec | 1.7 |
| 14 | 47 min 39 sec | 3 min 30 sec | 1.7 |
| 15 | 51 min 16 sec | 3 min 37 sec | 1.7 |
| 16 | 54 min 56 sec | 3 min 40 sec | 1.6 |
| 17 | 58 min 41 sec | 3 min 55 sec | 1.5 |
| 18 | 63 min 11 sec | 4 min 30 sec | 1.3 |
| 19 | 68 min 11 sec | 5 min | 1.2 |
| 20 | 73 min 31 sec | 5 min 20 sec | 1.1 |

20 laps = total 4000 yds in 73 min 31 sec
Average Speed = 1.7 knots

Figure B20

| OPEN WATER TIME/DISTANCE TRIAL<br>DPV #4 (MILITARY MODEL)<br>PROPELLOR PITCH SETTING 6, SWIMMING DIVER | | | |
|---|---|---|---|
| 200 YARD LAP | ELAPSED TIME | 200 YARD TIME | SPEED (KNOTS) |
| 1 | 3 min 21 sec | 3 min 21 sec | 1.8 |
| 2 | 6 min 42 sec | 3 min 21 sec | 1.8 |
| 3 | 10 min | 3 min 18 sec | 1.8 |
| 4 | 13 min 18 sec | 3 min 18 sec | 1.8 |
| 5 | 16 min 33 sec | 3 min 15 sec | 1.9 |
| 6 | 19 min 53 sec | 3 min 20 sec | 1.8 |
| 7 | 23 min 8 sec | 3 min 15 sec | 1.9 |
| 8 | 26 min 26 sec | 3 min 18 sec | 1.8 |
| 9 | 29 min 44 sec | 3 min 18 sec | 1.8 |
| 10 | 33 min 7 sec | 3 min 23 sec | 1.8 |
| 11 | 36 min 33 sec | 3 min 26 sec | 1.8 |
| 12 | 40 min 1 sec | 3 min 28 sec | 1.7 |
| 13 | 43 min 31 sec | 3 min 30 sec | 1.8 |
| 14 | 47 min 8 sec | 3 min 37 sec | 1.7 |
| 15 | 50 min 46 sec | 3 min 38 sec | 1.7 |
| 16 | 54 min 24 sec | 3 min 38 sec | 1.7 |
| 17 | 57 min 54 sec | 3 min 30 sec | 1.7 |
| 18 | 61 min 34 sec | 3 min 40 sec | 1.6 |
| 19 | 65 min 24 sec | 3 min 50 sec | 1.6 |
| 20 | 69 min 2 sec | 3 min 38 sec | 1.7 |
| 21 | 72 min 52 sec | 3 min 50 sec | 1.6 |
| 22 | 77 min 22 sec | 4 min 30 sec | 1.3 |

22 laps = total 4400 yds in 77 min 22 sec
Average Speed = 1.7 knots

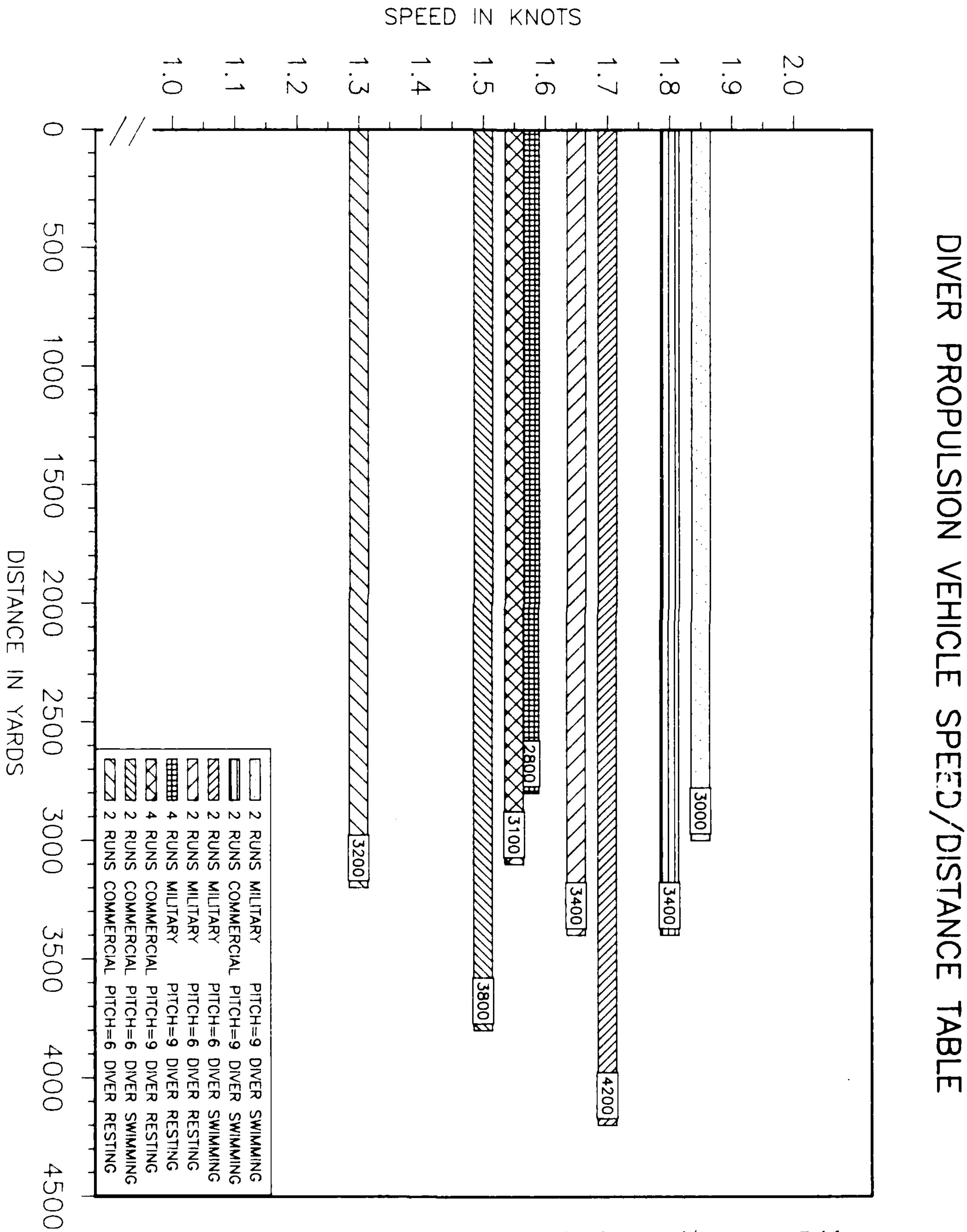



Figure B21. TEKNA Diver Propulsion Vehicle Speed/Distance Table

END
DATE
FILM
JAN
1988